農科大學

學術報告

第一卷

Tokyo. IMPERIAL UNIVERSITY.

College of Agriculture.

BULLETIN Vol. I.

1

明治二十六年

Tōkyō, Komaba, 1893.

CONTENTS OF VOLUME I.

BULLETIN I.

C. C. Georgeson. Fertilizer Experiments with Rice... ... 1

BULLETIN II.

O. Kellner. Researches on the Composition and Digestibility of Japanese Feeding Stuffs 1

BULLETIN III.

O. Kellner, and **Y. Mori.** Researches on the Composition, Treatment, and Application of Night-soil as a Manure 1

O. Kellner. On the Valuation of Japanese Fertilizers ... 27

BULLETIN IV.

O. Kellner. On the Composition of Several Japanese Fertilizers 1

BULLETIN V.

O. Kellner. Researches on the Distribution of Animal Nutrients over the Products obtained from Rice by Whitening 1

O. Kellner, Y. Mori, and **M. Nagaoka.** Researches on the Manufacture, Composition and Properties of "*Koji.*" 9

BULLETIN VI.

O. Kellner. Researches on the Composition of "*Miso.*"... 1

O. Kellner, Y. Kozai, Y. Mori, and **M. Nagaoka.** Experiments on the Effect of Several Nitrogenous Fertilizers on Crops 25

BULLETIN VII.

Y. Kozai. Researches on the Manufacture of Various Kinds of Tea 2

Y. Kozai. On the Nitrogenous Non-Albuminous Constituents of Bamboo Shoots 57

BULLETIN VIII.

O. Kellner, Y. Kozai, Y. Mori, and **M. Nagaoka.** Manuring Experiments with Paddy Rice 1

BULLETIN IX.

O. Kellner. Researches on the Action of Lime as a Manure, with special regard to Paddy Fields 1

O. Kellner, J. Yoshii, and **M. Nagaoka.** Experiments on the Cultivation of Lespedeza bicolor, Turcz. (*Hagi*) as a Forage Crop 26

BULLETIN X.

O. Kellner, Y. Kozai, Y. Mori, and **M. Nagaoka.** Manuring Experiments with Paddy Rice (second year) 1

BULLETIN XI.

O. Kellner, Y. Kazai, Y. Mori, and **M. Nagaoka.** Manuring Experiments with Paddy Rice (third year) 1

BULLETIN XII.

O. Kellner, Y. Kozai, Y. Mori, and **M. Nagaoka.** Comparative Experiments on the Various Phosphatie Fertilizers on Upland Soil 1

O. Kellner, and **M. Nagaoka.** Analysis of Rice Grain ... 23

Imperial College

OF

AGRICULTURE AND DENDROLOGY.

KOMABA, TOKIO, JAPAN.

BULLETIN NO. 1.

Fertilizer Experiments with Rice.

BY

C. C. GEORGESON, M. Sc.
(*Professor of Agriculture*).

TOKIO, JAPAN, DECEMBER, 1887.

Printed by "Tsukiji Kappan Seizosho,"
No. 17, Tsukiji Nichome, Tokio.

FERTILIZER EXPERIMENTS WITH RICE.

During the past season (1887) experiments were undertaken with a view to ascertain what influence the principal fertilizer elements have on the growth of the rice plant, both on paddy land and on upland. Some interesting results have been reached which are set forth in the following pages. A single season's experiments cannot, of course, establish anything definitely. But the results are of sufficient value to warrant their publication, as pointing to the elements which should predominate in the fertilizers applied to this crop, and indicating also, in the case of paddy land rice, their relative influence on the tillering of the plants, on the relative percentages of grain and straw, and on the size and weight of individual grains.

I PADDY LAND RICE.

Some difficulties present themselves in experimenting with this crop, due to the trouble in properly controlling irrigation. The arrangements of the rice fields in Japan, and their irrigation are models of perfection, admirably suited to the system of hand culture in vogue.

The whole field is divided into small level areas, varying from about $\frac{1}{4}$ to $\frac{1}{40}$ of an acre in extent, each enclosed by a slightly raised edging of green sward. These separate levels have a trifling elevation one above the other, so that the water running into the upper one will run over them all in succession, avoiding stagnation anywhere, and irrigating all levels thoroughly and alike, with a minimum of water. For

experimental purposes, however, this arrangement does not answer. Each plat must be supplied with water that has not been used on the others, and all with equal quantities. To secure these conditions the rice was planted in frames, each having an area of 9 square feet. These frames were placed some feet from each other, sunk about 1½ foot in the soil and projecting about five inches above the surface. The water for each was supplied from a small tub placed by its side, with a capacity of about 15 gallons. These tubs were filled as often as required, usually both morning and evening, care being taken, however, that equal quantities of water were supplied to all the frames. The water was let on in a constant stream through a spout with a small opening. A notch in the side of the frame provided an outlet for waste water, but the overflow was made as light as possible to avoid waste of the soluble fertilizers. The whole area between the frames was planted to rice and irrigated in the usual manner. The experimental plats were thus little independant areas in the rice field with their water level but very little above that common to the whole field. This contrivance had the disadvantage that the water thus confined in small quantities in the tubs and frames, became warmed by the sun somewhat more than in ordinary fields, and to that extent rendering the conditions abnormal. This extra warmth no doubt stimulated the growth of the plants; but for purposes of comparison it is of no consequence, as this stimulant was supplied to all frames alike.

FERTILIZERS.

Only three elements were supplied : nitrogen as sulphate of ammonia, potash as carbonate of potassium and phosphoric acid as superphosphate. The quantities were based on the demand of a *normal* crop with an allowance (30 *o/o* of $P_2 O_5$ and N. and 50 *o/o* $K_2 CO_3$) for loss through escaping water and none absorption by plants. The normal quantities pr. box were of

sulphate of ammonia.	49.25	grams.
carbonate of potassium	15.32	,,
superphosphate	21	,,

As shown in table I. they were applied in these and in double these normal quantities, singly, and in pairs, and all three together. They were mixed thoroughly with the soil to a depth of 6 inches before the water was let on, and the plants set out soon after.

PLANTS.

The plants were raised on a seed bed and transferred to the frames on June 20th, when they were about 9 inches high. Eighteen frames in all were planted, and each received 180 plants. Sixteen of the frames were fertilized and two (Nos.* 6 and 13) were left without manures. The crop was harvested Nov. 2d., then thoroughly air dried for two weeks and finally weighed and cleaned Nov. 16th.

---

* No. 6 has been omitted owing to accidental irregularity in the result.

TABLE I.

FERTILIZERS AND PRODUCT.

No. of Frame.	Fertilizers pr. Frame.	Grams.	Total weight of Crop grams.	Weight of Grain grams.	Weight of Straw grams.	Percent Grain.	Percent Straw.
1	Sulphate of Ammonium.	49.25	1,424	682.4	741.6	47.92	52.08
2	Carbonate of Potassium..	15.32	1,003	502.4	500.6	50.08	49.92
3	Superphosphate........	21.0	990	519.0	471.0	52.42	47.58
4	Sulphate of Ammonium. Superphosphate....... Carbonate of Potassium..	49.25 21.0 15.32	1,133	549.5	583.5	48.50	51.50
5	Sulphate of Ammonium. Superphosphate........ Carbonate of Potassium..	98.5 42.0 30.6	1,650	773.0	877.0	46.85	53.15
7	Carbonate of Potassium..	30.6	1,200	597.0	603.0	49.75	50.25
8	Superphosphate.......	42.0	684	353.5	330.5	51.68	48.32
9	Sulphate of Ammonium.	98.5	1,008	478.7	529.3	47.43	52.57
10	Nitrate of Sodium...... Superphosphate.. .... Carbonate of Potassium..	52.0 21.0 15.32	1,068	510.5	557.5	47.80	52.20
11	Sulphate of Ammonium. Superphosphate.......	49.25 21.0	812	400.0	412.0	49.26	50.74
12	Sulphate of Ammonium. Carbonate of Potassium..	49.25 15.32	1,097	545.3	551.7	49.70	50.30
13	No Manure...........		705	345	360	48.93	51.07
14	Superphosphate....... Carbonate of Potassium..	21.0 15.32	657	351.2	305.8	53.45	46.55
15	Sulphate of Ammonium. Superphosphate....... Carbonate of Potassium..	98.5 21.0 15.32	1,487	626.0	861.0	42.09	57.91
16	Sulphate of Ammonium. Superphosphate....... Carbonate of Potassium..	49.25 42.0 30.6	1,308	649.0	659.0	49.61	50.39
17	Superphosphate....... Carbonate of Potassium..	21.0 30.6	773	391.8	381.2	50.68	49.32
18	Superphosphate....... Carbonate of Potassium..	42.0 15.32	717	367.5	359.5	51.25	48.75

The preceding table shows the influence of the manure in a decided manure and with considerable regularity in the results. To make the figures more easily comprehended, the results are calculated in table II to the rates of manures and yields for acre which they approximately represent, and in the order of yield.

TABLE II.

RATES OF MANURES AND YIELDS PR. ACRE.

No. of Frame.	Manures.	lbs.	Yield Bush. Unhulled.	Yield Koku Unhulled.	Yield Koku Hulled.
	Sulphate of Ammonium.	1,040			
5	Superphosphate.......	444	180	36.4	24.56
	Carbonate of Potassium..	324			
1	Sulphate of Ammonium.	520	160	32.0	21.60
	Sulphate of Ammonium.	520			
16	Superphosphate.......	444	152	30.8	20.76
	Carbonate of Potassium..	324			
	Sulphate of Ammonium.	1,040			
15	Superphosphate.......	222	148	29.6	19.96
	Carbonate of Potassium..	162			
7	Carbonate of Potassium..	324	140	28.0	18.88
	Sulphate of Ammonium.	520			
4	Superphosphate.......	222	128	26.0	17.52
	Carbonate of Potassium..	162			
12	Sulphate of Ammonium.	520	127	25.6	17.4
	Carbonate of Potassium..	162			

No. of Frame.	Manures.	lbs.	Yield Bushels Unhulled.	Yield Koku Unhulled.	Yield Koku Hulled.
3	Superphosphate.......	222	122	24.4	16.56
	Superphosphate.......	222			
10	Carbonate of Potassium..	162	120	24.0	16.28
	Nitrate of Soda........	552			
2	Carbonate of Potassium..	162	116	23.6	16.0
9	Sulphate of Ammonium.	1,040	112	22.4	15.24
11	Sulphate of Ammonium.	520	92	18.8	12.76
	Superphosphate.......	222			
17	Carbonate of Potassium..	324	92	18.4	12.48
	Superphosphate.......	222			
18	Carbonate of Potassium..	162	84	17.2	11.68
	Superphosphate.......	444			
8	Superphosphate.......	444	82	16.8	11.48
14	Carbonate of Potassium..	162	81	16.6	11.2
	Superphosphate.......	222			
13	Unmanured..........		80	16.5	11.1

These yields appear very high. As already stated, the fact that the water used for irrigating the frames was warmed by the sun has in all probability had some effect on the growth. The average yield of irrigated rice about Tokio approximates 60 bushels of unhulled grain to the acre, and in the best rice growing districts the crop occasionally reaches 120 bushels to the acre. So it will be seen that, considering the quantities of fertilizers applied, the figures are not greatly at variance with the results obtained in practice. The yield at the rate of 80 bush. pr. acre, obtained in No. 13, is about one fourth higher than the crops gathered from adjoining rice fields.

In table III the yield in No. 13 is taken as the standard of comparison. The order of arrangement being the same as that given in the last table; the names of the fertilizers are omitted for the sake of brevity. The standard weights of manures pr. frame are those given for Nos. 1,2 and 3. (see table I.) corresponding respectively to 520 lbs. sulphate of ammonia, ~~444~~ 222 lbs. superphosphate and ~~324~~ 162 lbs. carbonate of potassium pr. acre. The only variation in these quantities was that they were in some cases doubled, and thus applied singly or in pairs or all together; in the latter case forming a complete fertilizer, a term used in table III for the sake of brevity. Taking 100 to represent the unmanured plat, column 1 gives the comparative yield of manured plats; column 2, the number of panicles in each plat (180 plants were set in each); column 3 gives the increase in the number of panicles by tillering; column 4 gives the weight of 1,000 sound grains; column 5 gives the weight of one Go (a small Japanese measure); column 6 the percentage of grain to the total weight of the crop, and column 7 the weight of grain per panicle. The weights are in grams.

TABLE III.

			1	2	3	4	5	6	7
Order of Yield.	No. of Frame.	Manures, (See also tables I and II).	Comparative yield.	Number of Panicles pr. Frame.	Panicles gained by Tillering.	Weight of 1000 grains. Grams.	Weight of one Go Grams.	o/o Grain.	Weight of Grain pr. Panicle. Grams.
17th	13	Unmanured...	100	230	50	28.7	100.2	48.93	1.50
1st	5	Complete (Double standard quant.)	224	427	247	26.8	101.1	46.85	1.55
2nd	1	Nitrogen (Standard quantity) ...	197	470	290	27.1	96.3	47.92	1.45
3rd	16	Complete (Double P_2O_5 & K_2O)...	188	314	134	27.5	104.8	48.85	2.06
4th	15	Complete (Double N.)..	181	376	187	27.0	95.2	42.09	1.66
5th	7	K_2CO_3 (Double standard quantity).	174	340	160	27.5	105.1	49.75	1.75
6th	4	Complete	159	405	225	27.0	107.1	48.50	1.35
7th	12	N. and K_2O.	158	313	133	28.0	96.3	49.70	1.74
8th	3	P_2O_5.	150	301	121	28.0	101.3	52.42	1.72
9th	10	Complete (N. as Nitrate of Soda)...	148	270	90	28.5	101.0	47.80	1.89
10th	2	K_2CO_3....	145	273	93	28.7	105.0	50.08	1.84
11th	9	N. (Double standard quantity). ...	138	404	224	26.5	94.5	47.43	1.18
12th	11	N. and P_2O_5.	116	286	106	28.5	97.5	49.26	1.40
13th	17	P_2O_5 and (Double standard K_2O)..	113	264	84	28.0	105.0	50.68	1.48
14th	18	K_2O and (Double P_2O_5).... ...	106	221	41	28.3	100.5	51.25	1.66
15th	8	P_2O_5 (Double quantity).	102	233	53	28.0	96.3	51.68	1.51
16th	14	P_2O_5 and K_2O.	102	228	48	28.0	101.6	53.45	1.54

EFFECTS OF NITROGEN.

As might have been expected, the highest yield was obtained from plat 5 to which a complete fertilizer was applied in large quantity. But the nitrogen is evidently the most active agent in bringing about this result; for the next highest yield is produced by sulphate of ammonia alone, and the two following both have nitrogen in considerable quantity. On the other hand, the four lowest yields are the products of fertilizers containing no nitrogen at all; and of the eight intermediate yields, from 5th to 12th inclusive, five contain nitrogen. The question which suggests itself, as to the quantity which limits the beneficial effects of nitrogen cannot be answered from these figures. But it appears that its influence for good was exceeded in the case of plat 9, which ranks only 11th in the order of yield, although it received double the standard quantity of sulphate of ammonia, while plat 1, to which was applied but half as much, ranks second. The inference must be that the nitrogen was so much in excess of the natural supply of the other necessary elements in the soil, as to be injurious to the development of the seed. This view is confirmed by a reference to the weights of the grain in columns 4 and 5, and to the amount of seed pr. panicle in column 7. The combination of nitrogen and potash produced a better yield than nitrogen and phosphoric acid, the former ranking 7th the latter 12th in the order of yield. With the single exception of plat 10, the nitrogen was furnished in the form of sulphate of ammonia. It was selected on purpose, as it has been proved by Dr. O. Kellner that irrigated rice prefers the nitrogen in the form of ammonia. Nitrification does not take place to any extent under water, and the plants absorb it as ammonia. This seems to be confirmed in the case of plat 10, where nitrate of soda was substituted for sulphate of ammonia, and although the plat was supplied with a complete fertilizer, in which was nitrate of soda at the rate of 552 lbs. pr. acre, it ranks but 9th in the order of yield and has much less influence on the tillering of the plants and the weight of the seed than ammonia.

By reference to column 3 in the last table it will be seen that nitrogen (as ammonia) has a most decided influence on the tillering of the rice plant. Hundred and eighty plants were set in each frame. The number of panicles harvested in excess of 180 is the result of the branching or tillering of the plants. I am convinced that the potent influence of the sulphate of ammonia in increasing the yield is due to a power it has of inducing the plants to send up new shoots from the roots. It not only has a stimulating effect on individual culms, causing them to grow tall and stout, but it increases their number—it stimulates the plant to produce more panicles to bear seed.

This view is strengthened by reference to the weights in columns 4 and 5, and to the percentage of grain to the whole crop in column 6. There it will be seen that the weight of a given number, or of a given measure, of grain grown under excessive nitrogenous stimulus, is below the average; and in plats 1 and 9, where nitrogen alone was furnished the panicles are also light (col.7). Hence whatever increase in the yield there is with this fertilizer above the normal, is due to an increase in the number of panicles. I consider that the experiment proves this beyond a doubt.

EFFECTS OF POTASH AND PHOSPHORIC ACID.

The effects of these two elements are less pronounced than that of nitrogen, and they are in consequence not so easily traced. Of the two, whether taken singly or in combination, potash appears to have influenced the yield most. It has a greater effect on the tillering of the plants, and compared with nitrogen it increases the weight of individual grains, as well as the percentage of grain to that of straw. Phosphoric acid, on the other hand, has but little if any influence on the growth of the straw, but it has a marked effect on the weight and percentage of the grain. In all cases where $P_2 O_5$ had a dominating influence the percentage of grain to that of straw is highest. And comparing cols. 4 and 5 it seems also to increase the size of the grain though not the density.

CONCLUSIONS.

The foregoing may be condensed into the following points:—

1st A complete fertilizer, the elements of which are properly proportioned to the needs of the plants, or to complement the defects of the soil, gives the best result.

2nd Of partial manures nitrogen, in the form of ammonia, appears to be most effective on irrigated rice.

3rd Nitrogen increases the yield by stimulating the plants to throw up shoots from the roots, thus increasing the number of seed bearing culms, and not by increasing the size of the panicle or the weight of the grain.

4th If nitrogen is applied in excess of the wants, individual grains do not attain normal size and weight.

5th Nitrogen increases the percentage of straw to that of grain more than other manures.

6th Phosphoric acid does not largely affect the yield, but it increases the size and weight of individual grains, and it increases the percentage of grain to that of straw.

7th Potash is intermediate in its effect between nitrogen and phosphoric acid: that is, it affects the yield more than phosphoric acid, but less than nitrogen; and it increases the percentage of grain to that of straw less than phosphoric acid, but more than nitrogen.

II UPLAND RICE.

Upland rice was sown on 24 plats June 2nd 1887, of which 22 were manured and two without manure.

Soil.—a light, porous, volcanic tufa, containing about 8 *o/o* of humus. It was cropped with sweet potatoes in 1886, and had then received a light coating of barnyard manure. The plats were 18 by 20 feet in extent (360 square feet). Three-foot paths, which intersected one another at right angles, separated each plat from its neighbors.

The Fertilizers consisted as in the case of irrigated rice, of nitrogen, potash and phosphoric acid. In this case the nitrogen was in the form of nitrate of soda, but the other two elements as before, in the shape of carbonate and superphosphate respectively. Each plat had 10 rows of rice, the rows two feet apart, and was subdivided into 5 divisions, a, b, c, d and e, each of which thus had two rows. The fertilizers were first weighed out for the whole plat; then divided by weight into five equal parts, corresponding to the five divisions, and thus applied. This was done, first, to note the variation in adjacent rows similarly treated and, secondly, for the purpose of testing the relative merits of the two common methods of applying artificial manures, viz. broadcasting and drilling. Divisions a, b and c were in all cases broadcasted, and divisions d, and e had the fertilizers applied in the drills with the seed. The broadcasted fertilizers were worked into the surface soil before the drills were opened and the seed sown. The 24 plats were divided into two series; series A including plats 1 to 12 and series B plats 13 to 24. Corresponding plats in the two series were manured with the same substances, the only difference being that the plats in series B received just twice the quantity given to the plats in series A. In table I corresponding plats of the two series are placed side by side to facilitate comparison. Plats 7 and 18 had no manure and the average of the two is taken as the standard of comparison for ascertaining the influence of the manures.

TABLE I.

No. of Plat.	Series A. Manures.	Grams.	Yield, (kilograms). Total Crop.	Grain.	% Grain.	Series B. Manures. Plat.	Grams.	Yield (kilograms) Total Crop.	Grain.	% Grain.
1	Carbonate of Potassium...	262	18.68	8.15	43.63	13	525	17.05	7.46	43.75
2	Carbonate of Potassium	262	19.21	8.42	43.83	14	525	21.24	9.40	44.72
	Superphosphate.	455					905			
3	Carbonate of Potassium	262	17.83	7.59	42.56	15	525	21.16	8.99	42.48
	Superphosphate.	455					905			
	Nitrate of Sodium.	680					1,360			
4	Carbonate of Potassium.	262	17.98	7.83	43.55	16	525	18.14	7.68	42.33
	Superphosphate	455					905			
	Nitrate of Sodium	340					680			
5	Superphosphate	455	17.59	7.84	44.57	17	905	17.50	7.95	45.43
6	Superphosphate.	455	17.99	7.78	43.25	19	905	20.08	9.22	45.91
	Nitrate of Sodium.	680					1,360			
7	No Manure.		13.96	6.14	43.98	18	None	15.97	6.96	43.58
8	Superphosphate	455	15.85	6.60	41.64	20	905	19.54	8.28	42.38
	Nitrate of Sodium	680					1,360			
	Carbonate of Potassium	131					262			
9	Nitrate of Sodium	680	16.32	6.85	41.97	21	1,360	17.55	7.39	42.11
10	Nitrate of Sodium.	680	19.31	8.24	42.67	22	1,360	16.14	6.75	41.82
	Carbonate of Potassium...	262					525			
11	Nitrate of Sodium.	680	19.03	7.90	41.51	23	1,360	19.19	7.77	40.49
	Carbonate of Potassium...	262					525			
	Superphosphate	225					455			
12	Sulphate of Ammonium	225	17.88	7.57	42.34	24	455	19.76	8.23	41.65
	Carbonate of Potassium	184					*1,360			
	Superphosphate.	455					905			

* Nitrate of Soda, this plat had no potash.

The maximum quantity of nitrogen furnished to the plats in series A is only half the quantity required by a normal crop; but in series B it is present in the amount required by the plant. The potash and phosphoric acid are supplied in series A according to the demands of a normal crop and in series B they are present in twice the necessary quantity. These proportions were adopted with a view to make the influence of the nitrogen more conspicuous by comparison. The results on this point are, however, not as satisfactory as could have been desired. In the majority of cases the nitrogen does not seem to materially increase the yield. The chief exception to this occurs in plat 19. On plat 17, 905 grams superphosphate produced a yield of 7.95 kilograms grain; while on plat 19 the same amount of superphosphate and an addition of 1,360 grams nitrate raised the yield to 9.22 kilograms grain. But in view of the uniformly slight increase in yield on the other plats to which nitrate was added, in some cases even apparently lowering the yield, the result in No. 19 should be regarded with suspicion, as it is probably owing to inequality in the soil. Even on plat 24 where there are the same amounts of superphosphate and nitrate, plus 455 grams sulphate of ammonium the yield is considerably less than on plat 19, and more in keeping with the results of nitrogen on the other plats. But perhaps the fairest estimate of its effects can be had from the results on plats 9 and 21, which were furnished with nitrate of sodium only. Plat 9 had a half dose, 182 lbs. pr. acre, and plat 21 had a full dose of 364 lbs. pr. acre. The yield on the unmanured plat in series A, (No. 7), was 6.14 kilograms grain; on plat 9 it was 6.85 kilograms a difference of 710 grams in favor of the nitrate, an increase equal to about 3.8 bushels pr. acre. Comparing the unmanured plat (18) with plat 21 in series B, we find the difference to be but 430 grams although the quantity of nitrate was doubled. The average of the two unmanured plats is 6.55 kilog.; the average of the two nitrate plats is 7.12, an increase of 570 grams in favor of the latter. If this may be taken to represent the normal increase in the yield of upland rice from an application of nitrate of

sodium to the amount stated, the influence of this fertilizer cannot be said to be great. The average of the quantities applied to the two plats is equivalent to a rate of about 273 lbs. pr. acre, while the increase in yield over the average of unmanured land is but about 3 bushels pr. acre, an increase far too small to justify the purchase of this fertilizer.

In the combinations of nitrate with the other two elements it is more difficult to form an opinion of its influence, since it cannot be determined with what percentage of the increase each deserves to be credited. On plat 1 potash alone produced a yield of 8.15 kilograms. On plat 10 the same amount of potash, (70 lbs. pr. acre), and 182 lbs. nitrate pr. acre, produced but 8.24 kilograms, an increase in the yield of the plat of but 90 grams, or less than half a bushel pr. acre. Does this small increase represent the influence of the nitrate? The superphosphate on plat 5, applied at the rate of 122 lbs. pr. acre produced a yield of 7.84 kilograms. On the adjoining plat, No. 6, the same quantity of superphosphate and 182 lbs. nitrate pr. acre, produced but 7.78 kilograms, a decrease of 60 grams from that of superphosphate alone; while on plat 19, similarly manured, but with twice the quantity, there is the only marked increase in yield that by any possibility can be ascribed to the nitrate. This case I have, however, already referred to. Again, on plats 3, 4, 11 and 12, where nitrogen is combined with superphosphate and potash, the yields are actually less than on the plats where the two latter were used singly and together. These results do not indicate that the nitrogen has had any influence on the yield, unless it be an adverse influence, and such a theory is scarcely admissible. The same general result will be observed in the corresponding plats of series B.

In one particular the nitrogen seems to have had some effect on the crop; not indeed, in the production of grain, but in that of straw. In the experiment with irrigated rice the sulphate of ammonia showed itself decidedly in the increase of the percentage of straw to that of grain. The same is the case here though in a less marked degree. If we take the average percentage of grain on the unmanured plats as the standard,

the effect of the nitrate has been to increase the weight of straw (or decrease the weight of grain) to the whole crop. What effect it had on the tillering of the plants could not well be ascertained as the crop stood somewhat thick in the rows and the original plants could not be pointed out. It is interesting to note that there is less grain in proportion to the straw in a crop of upland rice than there is in a crop of irrigated rice. The average per cent. of grain on the unmanured plats of the former was 43.78, leaving 56.22 *o/o* of straw, an excess of straw equal to 12.44 *o/o*; or the grain is to the straw as 100 : 128. On unmanured paddy land the grain was to the straw as 100 : 104. This does not include the roots in either case.

Potash and superphosphate at the rate pr. acre of 140 lbs. and 244 lbs. respectively produced the highest yield on plat 14, equal to about 50 bushels pr. acre. Plat 2, similarly manured, but with only half the quantity, produced at the rate of 44 bushels. The increase of 6 bushels must be credited to the greater quantity of manure on the former plat. It is to be noticed, however, that in four cases, the yields in series B falls below the yields on the corresponding plats in series A, which received less manure. How is this to be accounted for? In two of those cases the manure contained no superphosphate, in one cass it was supplied in but moderate quantity, (120 lbs. pr. acre on plat 23); while in only one case was it present in a quantity corresponding to that of the potash, 244 lbs. pr. acre on plat 16. But in all four cases carbonate of potash was supplied at the rate of 140 lbs. It is possible that 140 lbs. of this somewhat caustic substance was too much for the good of the plants, but that in the cases where superphosphate was also supplied in considerable quantity, a reaction may have set in to ameliorate its action on the plant; the free sulphuric acid of the superphosphate, uniting with a portion of the potash to form the neutral sulphate of potassium. Used in moderate quantity, potash had decidedly a beneficial influence on the yield.

Superphosphate also increased the yield. And the same

effect is noticeable here as was noticed in the case of irrigated rice; namely that this fertilizer increases the percentage of grain compared with that of straw. The plats on which the superphosphate had a dominating influence show in all cases the highest percentages of grain.

The following table shows the rate at which the manures were applied pr. acre in pounds, and also the approximate rate of yield in bushels. It also shows the comparative yields of the several plats in which the average of the two unmanured plats is taken as hundred.

Rates of Manures and Yield pr. Acre.

Series A. Plat.	Manures.	lbs.	Yield Bushels.	Unmanured equals 100.	Series B. Plat.	Manures lbs.	Yield Bushels.	Unmanured equals 100.
1	Carbonate of Potassium	70	43	124.4	13	140	39	113.9
2	Carbonate of Potassium.	70	44	128.5	14	140	50	143.5
	Superphosphate	122				244		
3	Carbonate of Potassium...	70	40.4	115.8	15	140	48	137.2
	Superphosphate	122				244		
	Nitrate of Sodium	182				364		
4	Carbonate of Potassium	70	42	119.5	16	140	41	117.2
	Superphosphate.	122				244		
	Nitrate of Sodium	90				180		
5	Superphosphate	122	42	119.7	17	244	42.3	121.3
6	Superphosphate	122	41.4	117.2	19	244	49	140.7
	Nitrate of Sodium	182				364		
7	No Manure			† 100	18		† 34.8	
8	Superphosphate.	122	35.1	100.7	20	244	44	124.8
	Nitrate of Sodium	182				364		
	Carbonate of Potassium...	131				262		
9	Nitrate of Sodium	182	36.4	104.5	21	364	39.3	111.3
10	Nitrate of Potassium.	182	43.8	125.8	22	364	35.9	103.0
	Carbonate of Potassium	70				140		
11	Nitrate of Sodium	182	42	120.6	23	364	41.3	118.6
	Carbonate of Potassium	70				140		
	Superphosphate.	60				120		
12	Sulphate of Ammonium	60	40.3	115.5	24	120	43.7	125.6
	Carbonate of Potassium...	49				* 364		
	Superphosphate	122				244		

* Nitrate of Soda, this plat had no potash. † Average of the two unmanured plats.

DRILLING *versus* BROADCASTING THE FERTILIZERS.

Concerning the effect on the yield of applying the manures in the drill with the seed, as against broadcasting and working them into the surface soil before sowing, the results are rather interesting. The averages of the division d and e, on which the manures were drilled with the seed, were equal to, or higher, on 14 of the 22 manured plats, than the averages of the divisions a, b and c, on which the manures were broadcasted. This does not argue in favor of broadcasting as some experimenters advocate. There is no doubt, however, that concentrated manures may act injuriously when applied with the seed in too large quantity.

In one of the eight cases in which the drilled fertilizers produced a less yield than the broadcasted ones, nitrate alone was used (plat 9), in one case superphosphate alone (plat 17), in two cases nitrates were dominant (plats 11 and 22), In one case superphosphate dominated (plat 12), one plat (No. 2) had no nitrate, and in the remaining two cases (plats 15 and 16) all three elements were present in large quantity.

Researches
On the Composition and Digestibility of Japanese Feeding Stuffs.

By Dr. O. Kellner.

Investigations into the general laws of animal nutrition as well as into those which are more specially connected with the feeding of domestic animals, have been most eagerly and assiduously carried on during the last 30 years in Germany, where J. von Liebig gave a mighty impulse to such researches by his treatise: die Thierchemie oder die organische Chemie in ihrer Anwendung auf Physiologie und Pathologie (Animal or Organic Chemistry applied to Physiology and Pathology). There were particularly C. von Voit and M. von Pettenkofer and their pupils, who established by systematical investigations a theory of animal nutrition, the foundation, upon which W. Henneberg and F. Stohmann, E. von Wolff, G. Kühn and others built up the principles of the rational feeding of live-stock.

The first practical subject to be experimented on was suggested by the demand of each class of farm animals for really *digestible* nutrients, and the results of such researches were the so-called *"feeding standards,"* which are simply concise statements of those amounts of digestible protein, fát and carbohydrates found to be *in general* best adapted to the purpose in view. For example, the feeding standard for sheep of the coarse-wooled breeds, kept for wool production is according to E. von Wolff, as follows:

For 1000 Kilograms of live-weight per day,

Total organic matter...	...	20.0	Kilograms.
Digestible crude protein ...	...	1.2	„
„ carbohydrates ...	...	10.3	„
„ fat	...	0.2	„

This means that a good growth of wool will be secured by any mixture of suitable feeding stuffs from which 1000 Kilograms of living sheep can daily extract 1.2 Kilograms of crude protein, 10.3 Kilograms of carbohydrates and 0.2 Kilograms of fat and the total bulk of which is approximately indicated by the amount of total organic matter (20 Kilograms).

Rations that approximately coincide with the feeding standards, can, of course, only be compounded, when it is known how much of each digestible nutrient is contained in the several feeding stuffs. Hence arose the necessity to determine the *digestibility* of the fodders in those conditions of preparation (raw, cooked, steamed, fermented, green, dried, etc.) and stages of growth in which they are commonly used. Experiments of this kind have likewise formed of late years a prominent part of the work of the German Experiment Stations. Nearly 3000 different sorts of feeding stuffs have already been submitted there to trials with animals and their minimum, maximum and average contents of digestible nutrients ascertained. The results thus obtained were tabulated and are in the hands of all educated farmers, who are thus enabled to feed their live-stock without running the risk of giving too little or too much food.

The feeding standards are valid at least for all moderate climates, as the changes of heat have, within ordinary limits, but little influence on the destruction or deposition of nutrients in the animal body; hence they can be safely applied also in this country.—With regard to the feeding

stuffs, however, the matter is different. The concentrated feeding stuffs, such as grains, seeds, tubers and roots, seem, it is true, to be, fortunately, only very slightly concerned by climatic conditions as is sufficiently proved by the analyses hitherto made, wherefore the respective results obtained in other countries can be safely made use of here also ; but the coarse fodders (green crops, day and straw) are greatly influenced by the climate. Not only does the same kind of a fodder plant show quite different nutritive properties at different conditions of heat, light and moisture (rain), but, as a matter of the greatest importance, the character of the vegetation, the kinds of the wild plants growing on natural uncultivated land, which so largely participate in the nutrition of live-stock, are quite dependent on the climate.

The line to be followed in the investigations into cattle feeding in Japan is hereby clearly indicated : the first thing to be done is to examine and ascertain the composition and digestibility of the common, coarse fodders and of those concentrated feeding stuffs which are peculiar to this country, in order to enable judicious feeders to avail themselves of the feeding standards. A few contributions to this subject are contained in the following pages.*

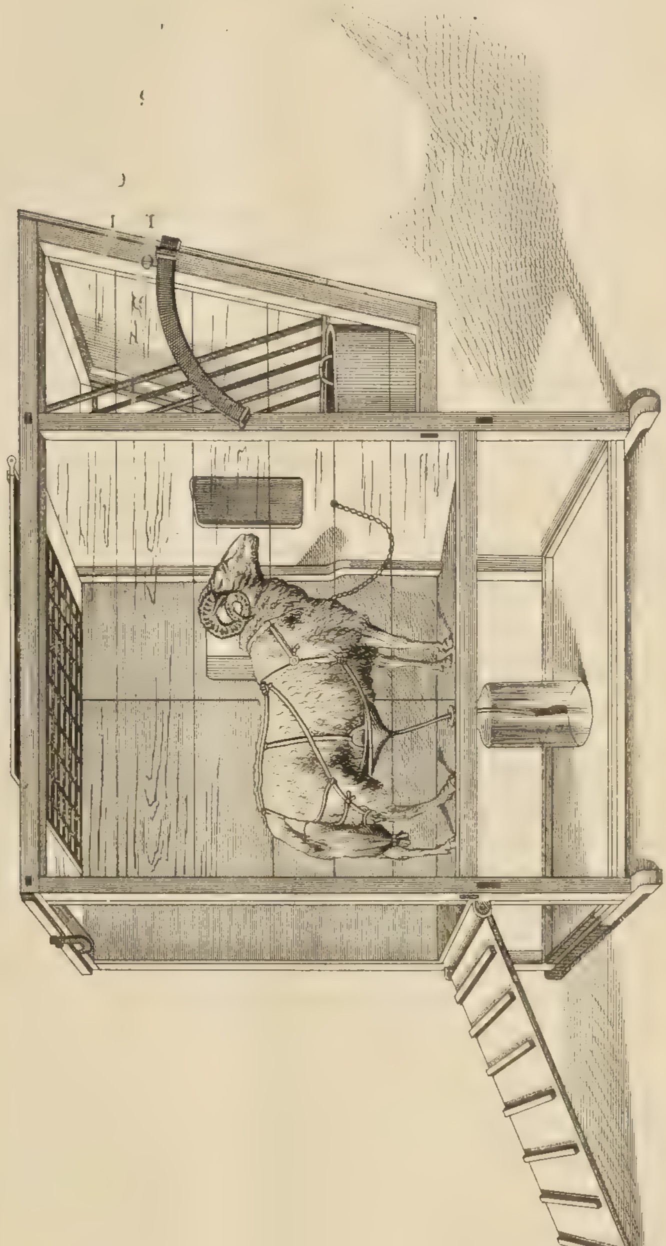
Digestion Experiments.

A. Coarse Fodders.

The methods followed in these researches were those generally adopted by the German authors. Every trial was made in duplicate and the animals employed were sheep, partly Merinos, partly Southdowns. Until 1885 there were unfortunately only rams available, later on we employed wethers. Each animal was supplied three times daily with food, at 7 a.m. 12 noon and 6 p.m., the whole of the food

* Some of these researches have already been published in German in "Landwirthschaftliche Versuchsstationen," vol. 32, 1885, p. 72.

being weighed out in the morning and uniformly distributed over the three meals. Drinking water was given ad libitum, a sufficient quantity was likewise weighed in the morning and what was left was determined after 24 hours. Common salt was regularly given every meal, 6—10 Grms. per day, according to the general appetite of the animals for the food under experiment. During the trial each animal was kept in a separate box without litter, on a cemented floor which was cleaned several times per day from urine, in order to prevent the small particles of food scattered by the sheep from being polluted. The small amount of scattered food was always carefully collected and put back into the mangers, which had been so constructed as to hinder the animal from freely moving the head while eating, in order to prevent their scattering of the food as much as possible. In the winter of 1884/85 so called "feeding boxes," constructed by Henneberg for such experiments (see the illustration on the next page) were procured and thenceforward exclusively used. These consist of a two-storied case, the upper part of which is just spacious enough to allow a sheep to lie down or stand up freely without allowing it to turn or to draw the head easily out from the manger. The latter contains a shallow dish of tinned sheet iron, closely fitted into and filling out the whole manger, which is also furnished with a rack. The side of the box behind the sheep admits of being let down so as to form a sort of ladder, on which the animals can be easily guided into or out from the box. The lower story was just so high as to admit of placing a bottle there for the reception of the urine guided into that vessel through a rubber pipe, which formed the tail of a large rubber funnel buckled on the sheep in proper position. The fæces of the animals were collected in a bag of rubber cloth, fastened to the sheep by means of several girdles, which arrangement had likewise been used during the earlier trials since 1882. The contents of this



bag were emptied several times a day into a capacious beaker and kept covered. Every 24 hours, in the morning, before giving the food, the fæces were weighed, well mixed and an aliquot part usually 1/10, taken for the analysis. Besides this the animals were weighed every morning, before they were fed. The feeding boxes just described have the advantage that they prevent the scattering of food almost completely, preclude entirely that food comes in contact with excreta, admit of a complete collection of the urine, and afford the greatest cleanliness during the whole trial.

As ruminants retain the food several days in the body, before the undigestible portions of it are ejected, it is necessary to continue with the feeding of the ration under experiment for at least 5-6 days before samples of excreta are taken for the analysis. The digestion experiments are accordingly divided into a preliminary or preparatory period of at least 6 days and a main period of 6-8 days. We commenced the main period only after the animals had for 6-8 days consumed their ration either totally, or at least so uniformily that the uneaten residues did not vary greatly from day to day. The residues of the ration, and the fæces, were collected only during the main period, aliquot portions of each substance were then taken every day, dried in a steam bath and afterwards mixed and analyzed. Of the food samples for analysis were collected three times, viz. 2 days before commencing the main period, 4 days after this time, and 3 days before closing the trial.

The fodders, uneaten residues and fæces were analyzed in the usual way. We determined the dry matter by drying the substance to constant weight at 100-110° C, the total nitrogen until 1886 by Will-Varrentrapp's method and thereafter by that of Kjeldahl, the albuminoid nitrogen by precipitation with hydrated cupric oxide, the crude fat by extraction of the dried substance with absolute ether, the crude fibre by Henneberg's acid and alkali method,

deducting always the nitrogenous matters and ash from the raw fibre found. The ash was estimated after incineration and determination of the carbon and carbon dioxide contained therein, which were deducted from the raw ash. For the sake of simplicity, we use, in the following pages, the terms of "fat," "fibre," "ash," instead of always repeating, "crude fat," "crude fibre, free from nitrogenous substances and ash" and "pure ash, free from C and CO_2."

In the calculation of the digestibility the contents of the fæces were simply taken as undigested food ingredients, although it is known that they are mixed with some digestive and other juices, mucin, epithelial cells, etc., which I have shown to be considerable enough to alter materially the numbers for the digestible crude protein. We did not beforehand take account of those facts, because the feeding standards as well as the tables on the digestibility of feeding stuffs have also been compiled without knowing them. Besides this the nitrogen admixed with the fæces in the digestive canal is approximately dependent upon the total dry matter digested, as I have formerly found. The figures calculated in the present paper might consequently be easily corrected, if any necessity would arise in future.

I. Common Japanese Hay.

This hay is made from the mixed grasses growing on the dykes and ditches of paddy land and is cured toward the middle and close of the summer, while the first cutting serves usually as manure for the rice fields. It is composed of short-stalked soft plants, but frequently contains much dust and earthy materials, as it is mostly cured on the road-side, or on the road itself.

The first trial was made by Mr. *J. Sawano* in the winter of 1882/83 with two rams, No. I a Merino, No. II a Southdown, both of which received a ration of 1 Kilogram besides 6 grams of common salt per day and head. The Merino consumed his food completely, but the Southdown left small quantities every day, amounting during the whole main period of 8 days to 402 Grams air-day = 329.8 Grams dry substance, which had to be deducted, at the calculation of the digestibility, from the ration given.

The consumption of water and the excretion of fæces were during the main period as follows (in Grams):

December.	Water drunk.		Fresh fæces.	
1882	No. I.	No. II.	No. I.	No. II.
11.	2180	1720	1597	1684
12.	1650	1920	1363	1743
13.	1725	1720	1370	1738
14.	1730	1700	1479	1733
15.	1475	1625	1334	1683
16.	2000	1485	1393	1575
17.	1410	1460	1327	1475
18.	1775	1210	1395	1237
Daily average	1744	1618	1407.55	1609.0

The chemical analysis of the hay and fæces gave the following results :—

	Hay. %	Fæces. Sheep No. I. %	Fæces. Sheep No. II. %
Water	17.55	70.10	77.46
In the dry matter :			
Crude protein...........	9.89	11.11	11.88
Fat	2.61	2.93	2.81
Fibre	35.27	26.50	25.66
Nitrogenfree extract...	42.20	42.69	42.27
Ash	10.03	16.77	17.68
Total Nitrogen	1.583	1.779	1.902
Albuminoid nitrogen ..	1.382	1.636	1.700

The so-called coefficients of digestibility, e. g. the amount digested out of 100 parts of each constituent, are the following, based on the preceding data :—

	Dry substance Grams.	Organic substance Grams.	Crude protein Grams.	Fat Grams.	Fibre Grams.	Nitrogenfree extract Grams.
Sheep No. I.						
Consumed	824.53	741.83	81.55	21.51	290.81	347.95
Excreted	420.78	350.22	46.75	12.33	111.51	179.63
Digested	403.75	391.61	34.80	9.18	179.30	168.32
Digested in percent...	48.97	52.79	42.67	42.68	61.66	48.38
Sheep No. II.						
Consumed	787.43	704.73	77.47	20.43	276.27	330.55
Excreted	362.65	298.53	43.08	10.19	91.98	153.28
Digested..................	424.78	406.20	34.39	10.24	184.28	177.27
Digested in percent...	53.94	57.64	44.39	50.12	66.70	56.65
Coefficients in average of the two trials......	51.46	55.22	43.53	46.40	64.18	52.02

In 1883 another sort of hay of the same origin was examined in regard to its composition and digestibility by Mr. *K. Makino.* The animals used were Merino rams. They were supplied per day and head with 1 Kilogram of hay and 7 Grams of common salt, which were completely consumed. The quantity of water drunk, the live-weight, and the excreta ejected were during the main period as follows:—

Desember.	Water consumed in Grams.		Live-weight in Kilograms.		Fæces in Grams.	
1883	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
13.	—	—	37.7	35.0	1200.0	2018.5
14.	2200	2790	35.4	35.5	1224.5	2001.5
15.	1950	2750	36.2	36.0	1125.0	2599.0
16.	1810	2180	36.5	36.0	1210.5	2369.0
17.	1940	3200	36.8	35.5	1072.0	1841.0
18.	2460	1710	37.2	36.3	1268.0	2141.0
19.	1690	2426	37.8	35.4	1302.0	1985.0
20.	2000	1900	36.8	35.4	1170.0	1789.0
In average	2007	2422	36.8	35.6	1196.5	2093,0

The percentage composition of the food and fæces as found by analysis was :—

	Hay.	Fæces. Sheep No. I.	Fæces. Sheep No. II.
Water...	16.86	71.02	83.23
In the dry matter:			
Crude protein	12.24	11.60	11.24
Fat...	3.10	3.85	3.87
Fibre	33.20	28.27	26.58
Nitrogenfree extract	42.31	42.21	43.48
Ash	9.15	14.07	14.33
Total nitrogen	1.866	1.790	1.684
Albuminoid nitrogen	1.515	—	—

Herefrom the daily consumption, excretion and digestion are calculated in the following :

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Consumed................	831.41	755.34	101.75	25.77	276.06	351.76
Excreted	346.73	297.95	40.21	13.35	98.03	146.36
Digested................	484.68	457.39	61.54	12.42	178.03	205.40
Digested in percent...	58.30	60.55	60.48	48.19	64.49	58.39
Sheep No. II.						
Consumed................	831.41	755.34	101.75	25.77	276.06	351.76
Excreted	351.02	298.78	39.47	13.58	93.32	152.41
Digested................	480.39	456.56	61.28	12.19	182.74	199.35
Digested in percent...	57.78	60.44	60.23	47.30	66.20	56.67
Coefficients in average of the two trials.....	58.04	60.50	60.36	47.75	65.34	57.53

A third specimen of hay from dykes and ditches of paddy land was subjected to an experiment by Mr. *Y. Kozai* in November 1885. Judging from the mere appearance of this fodder it seemed even to be inferior to the specimens axamined in the preceding years. The animals obstinately refused to consume totally the usual experimental ration of 1 Kilogrm., wherefore the quantity laid before them had to be reduced to only 750 Grams in order to approach closer to a complete consumption.

The quantities of hay left uneaten, water consumed, fæces, as well as the live-weights are contained in the following table:

November.	Hay left in Grams.		Water consumed in Grams.		Fæces in Grams.		Live-Weight in Kilograms.	
1885	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
22.	19	32	900	1050	1014.5	966.5	24.0	25.0
23.	24	52	1340	1460	1145.5	1000.5	24.3	25.2
24.	22	53	1080	1250	1068.0	925.0	24.2	25.5
25.	47	41	880	1080	1042.5	960.0	24.3	25.3
26.	43	49	1150	640	1036.5	1100.5	24.5	25.0
27.	40	48	1430	1400	1049.5	890.0	24.1	24.9
28.	29	36	1040	740	985.5	961.5	24.0	24.8
29.	22	40	1460	1310	1101.5	1038.0	24.0	24.3
Per day	30.8	44	—	—	1055.4	980.8	—	—

There was 13.03 % moisture in the hay, 19.54 % in the residues of the fodder of sheep No. I, 20.87 in those of sheep No. II, 68.68 % in the fæces of sheep No. I, and 67.02 in those of sheep No. II. As the quantity of food left uneaten was very small, and consisted of the same material in both cases, the analysis was made of a mixture of them.

The food, the residues and fæces had the following composition, per cent:

	Hay.	Residues.	Fæces. Sheep No. I.	Fæces. Sheep No. II.
Crude	9.29	7.03	11.65	11.69
Fat	3.34	1.69	3.23	3.18
Fibre	32.59	33.65	26.53	26.66
Nitrogenfree extract.	45.63	37.02	41.93	41.57
Ash	9.15	20.61	16.66	16.90

The daily quantities eaten, excreted and digested are calculated in the following table:

	Total Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Hay given...............	652.28	592.60	60.60	21.78	214.93	295.28
„ left...................	24.78	19.60	1.74	0.42	8.34	9.16
„ consumed.........	627.50	572.94	58.80	21.36	206.59	286.12
Excreted	330.55	275.48	38.51	10.68	87.69	13.86
Digested..................	296.95	297.46	20.35	10.68	118.90	272.26
Digested in percent of each constituent.....	47.32	51.90	34.59	50.00	57.05	51.58
Sheep No. II.						
Hay given...............	652.28	592.60	60.60	21.78	214.93	295.28
„ left...................	34.82	27.64	2.45	0.59	11.72	12.98
„ consumed.........	617.46	564.96	58.10	21.19	203.21	282.30
Excreted	323.46	268.80	37.81	10.30	86.23	134.46
Digested..................	294.00	296.10	20.34	10.89	216.98	147.84
Digested in percent... of each constituent.	47.60	52.25	34.56	50.14	57.07	52.32
Coefficients in average of the two trials.....	47.46	52.07	34.57	50.07	57.06	51.96

The three experiments, made at different times and on three different specimens of hay from the dykes and ditches of paddy land, will admit of a reliable valuation of this kind of fodder. As to the composition, which we may consider first, the three specimens do not show any great variability; the dry matter contained:—

	No. I.	No. II.	No. III.	Average.
Crude protein	9.89	12.24	9.29	10.47
Fat	2.61	3.10	3.34	3.02
Fibre	35.27	33.20	32.59	33.71
Nitrogenfree extract	42.20	42.31	45.63	43.36
Ash	10.03	9.15	9.15	9.44

As there exist no extensive or remarkable researches on the feeding stuffs of countries resembling Japan in their climatical conditions, and as a reliable basis for the valuation of foods has hitherto only been established in Germany, we are for the purpose of comparison compelled to resort to the figures formulated in the latter country. The various kinds of meadow hay grown there will be best suited as a standard, because meadows, like paddy fields, are situated in low places along the banks of rivers and composed of mixed grasses and herbage, from which hay is gained by several cuttings every year. According to the tables given by *E. von Wolff* we may distinguish 5 qualities of meadow hay, viz. excellent, which represents the young grasses of a rich pasture, very good, medium good, rather poor and inferior, which latter 4 kinds only are usually cured from meadows. The percentage composition of these 5 sorts of hay in the waterfree state is shown by the following figures:

	Excellent.	Very good.	Medium good.	Rather poor.	Inferior.
Crude protein	16.1	13.8	11.3	10.7	8.8
Fat...	3.6	3.3	2.9	2.3	1.8
Fibre	22.9	25.8	30.7	34.1	39.1
Nitrogenfree extract	48.2	48.9	47.9	46.6	44.4
Ash...	9.2	8.2	7.2	6.3	5.9

As the nutritive value of coarse fodders depends upon their containing a high percentage of albuminoids and a low proportion of fibre, we find upon comparing the composition of the three specimens examined in our laboratory with the figures of Wolff, that the common Japanese hay would be regarded in central Europe as "*rather poor.*" Of our three kinds of hay Nos. I and III are nearly of the same composition while No. II is a little better, and approaches the medium good meadow grass.

Almost the same valuation is arrived at, if the proportion of digestible nutrients is taken into acconnt. There is contained in 100 parts of dry matter:

	Hay No. I.	Hay No. II.	Hay No. III.	Average.
Digestible crude protein	4.29	7.39	3.21	4.96
„ carbohydrates and fat.	46.76	49.73	45.50	47.33

According to Wolff's tables German hay contains:

	Excellent.	Very good.	Medium good.	Rather poor.	Inferior.
Dig. crude protein...	10.95	8.70	6.30	5.38	3.97
„ carbohydrates and fat	55.75	53.07	50.40	44.65	42.08

Viewed from these latter contents the hay Nos. I and III can hardly be classified as "rather poor," because their content of digestible protein is too low, while the specimen No. II well deserves to be called "medium good." The general result of our investigation shows that the hay obtained from the roadsides, dykes and ditches of paddy fields has a lower quality than that which is regarded in central Europe as medium good.

II. Hay from Uncultivated Land (Hara).

Researches on two specimens of hay from haras have been made by Mr. *H. Tamai*, one of the most successful students of our college, who, to our great regret, succumbed this year to a cruel disease.

No. I of the specimens had been procured from Iwashiro, No. II from the Imperial farm at Shimōsa. Both consisted in their majority of Eulalia japonica (Kaya), a tall, harsh grass, which generally makes up the bulk of the plants on recent volcanic formations in Japan. No. 1 contained a little more of Papilionaceæ, chiefly Lespedeza cyrtobotrya (Hagi), and Compositæ than No. II which was remarkable for its content of Equisetum arvense. The composition of the two specimens was as follows:

	No. I.	No. II.
Moisture...	15.86 %	14.87 %
In 100 p. dry matter:		
Crude protein	8.85	6.98
Crude fat	3.41	3.26
Fibre...	40.41	40.46
Nitrogen free extract ...	40.03	42.47
Ash (free from CO_2)... ...	7.30	6.83

The two kinds of hay as shown by these figures are of a very low quality, so poor, indeed, in nutritious components that we may look in vain through the whole list of agricultural literature for specimens of mixed grasses of known nutritive qualities, which would equal them. They are hardly better than rice straw cut before dead ripeness, the composition of which will be found in a later part of this paper.

Owing to the very inferior condition of the hay the animals, two sheep of the Merino breed, with which the digestion experiment was carried out, refused for several days to eat a quantity sufficient for a reliable trial. It was but by slow degrees that they became accustomed to it, wherefore the preliminary period of feeding had to be continued, with the hay first given, for 12 days. As in researches on the digestibility of a feeding stuff much depends on as complete a consumption as possible of the food laid before the animals, the daily ration had to be cut down to 800 Grams per head. Even this small quantity was not totally consumed, but of the hay No. I more than $^1/_4$, of No. II more than $^1/_3$ was left uneaten and had to be collected and analyzed. The following figures show the averages of the 8 days of the main period of the trial:

Total dry substance:

		Sheep No. I.	Sheep No. II.
Hay No. I.—	Daily ration... ...	673.15 Grams.	673.15 Grams.
	Left uneaten ...	155.72 „	197.88 „
	Consumed	517.43 „	475.27 „
	Consumed in pct. of the hay given	76.87 „	70.60 „
Hay No. II.—	Daily ration... ...	681.04 Grams.	681.04 Grams.
	Left uneaten ...	263.99 „	204.10 „
	Consumed	417.05 „	476.94 „
	Consumed in pct. of the hay given	61.23 „	70.03 „

Quantity of fæces per day:

Hay No. I.	280.10 Grams.	230.00 Grams.
„ „ II.	223.50 „	245.50 „

The analysis of the residues left uneaten, and fæces, gave the following results, percent of the dry substance:

I. Residues.

	Hay No. I.		Hay No. II.	
	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
Crude protein	8.56	6.96	7.20	6.93
Crude fat...	2.60	2.74	2.37	2.22
Fibre	36.75	39.74	38.33	45.03
Nitrogenfree extract	44.51	43.90	45.36	39.81
Ash...	7.58	6.66	6.74	6.01

II. Fæces.

Crude protein	10.55	10.79	9.66	10.52
Crude fat...	3.77	4.38	4.26	4.21
Fibre	28.38	28.47	28.38	27.71
Nitrogenfree extract	42.62	42.12	47.30	46.85
Ash	14.68	14.24	10.40	10.71

From these data the daily consumption, excretion and digestion of each single component of the food are calculated in the following table:

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Crude fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
I. Hay from Iwashiro. Sheep No. I.						
Daily ration............	673.15	624.00	59.57	22.95	272.02	269.46
Left uneaten...........	155.72	143.93	13.33	4.05	57.24	69.31
Consumed...............	517.43	480.07	46.24	18.90	214.78	200.15
Ejected (fæces).........	280.10	238.98	29.55	10.56	79.49	119.38
Digested	237.33	241.09	16.69	8.34	135.29	80.77
,, in pct. of each component......	45.87	50.22	36.09	44.13	62.99	40.36
Sheep No. II.						
Daily ration............	673.15	624.00	59.57	22.95	272.02	269.46
Left uneaten...........	197.88	184.70	13.77	5.42	78.64	86.87
Consumed...............	475.27	439.30	45.80	17.53	193.38	182.59
Ejected (fæces).........	230.00	197.25	24.82	10.07	65.48	96.88
Digested..................	245.27	242.05	20.98	7.46	127.90	85.71
,, in pct. of each component......	51.61	55.10	45.81	42.56	66.14	46.94
II. Hay from Shimosa. Sheep No. I.						
Daily ration............	681.04	634.53	47.54	22.20	275.55	289 24
Left uneaten...........	263.99	246.20	19.01	6.25	101.16	119.78
Consumed...............	417.05	388.33	28.53	15.95	174.39	169.46
Ejected (fæces).........	223.50	200.26	21.59	9.52	63.43	105.72
Digested..................	193.55	188.07	6.94	6.43	110.96	63.74
,, in pct. of each component.....	46.40	48.43	24.33	40.31	63.63	37.61
Sheep No. II.						
Daily ration............	681.04	634.53	47.54	22.20	275.55	289.24
Left uneaten...........	204.10	191.83	14.14	4.53	91.91	81.25
Consumed...............	476.94	442.70	33.40	17.67	183.65	207 99
Ejected (fæces)..........	245.50	219.20	25.83	10.33	68.03	115.01
Digested..................	231.44	223.50	7.57	7.34	115.61	92.98
,, in pcts. of each component.....	48.52	50.48	22.67	41.54	62.95	44.70

The average digestion coefficients, e. g. the amount of each component digested, out of 100 parts consumed, are:

	Hay from Iwashiro.	Hay from Shimosa.
Total dry matter	48.7	47.5
Organic matter	52.7	49.5
Crude protein...	41.0	23.5
Fat	43.3	40.9
Fibre	64.6	63.3
Nitrogenfree extract	43.7	41.2

Not regarding that 25 and 35 pct. respectively of the hay were left uneaten in our experiments, and that coarse fodders of such quality will hardly be totally consumed by farm animals, the contents of the two specimens in digestible nutrients, calculated with the help of the coefficients, are found to be as follows:—

	Iwashiro.	Shimosa.
Digestible crude protein	3.63 %	1.64 %
„ carbohydrates and fat ...	47.25 „	46.36 „

Compared with the contents of meadow hay as given in Wolff's tables (p. 13) we are hardly justified in attributing the name of "hay" to these fodders; they properly deserve to be designated as "*straw*" with regard to their nutritive value, as well as to their utilization on the farm.

III. Hay from Imperata arundinacea (Chigaya).

Imperata arundinacea is a harsh tall grass, which makes up the bulk of vegetation on the slopes of uncultivated hills and mountains, as well as on the waste land of the plains. A specimen of hay made from this plant was examined in the winter of 1882 by Mr. *T. Yoshii.* Two rams, No. I a Merino, No. II a Southdown, received per day and head 1 Kilogram, but did not consume this ration completely. Sheep No. I left very considerable quantities, (nearly 350 Grams), every day, while the other animal consumed little more than 900 Grams. The residues were collected every day and separately analyzed.

The quantity of hay left uneaten, the amount of water drunk, the proportion of fæces and the variations of the live-weights are shown by the following table :—

1882.	Sheep No. I.				Sheep No. II.			
	Residues left. Grams.	Water drunk. Grams.	Fæces. Grams.	Live-weight. Kilog.	Residues left. Grams.	Water drunk. Grams.	Fæces. Grams.	Live-weight. Kilog.
Nov. 29.	419	740	619	32.7	95	3010	1010 0	35.0
,, 30.	450	2000	655	32.5	93	2620	1410.5	35.1
Dec. 1.	352	2600	669	33.0	161.7	3000	1700.5	37.0
,, 2.	400	910	629	33.3	75	1710	1448.5	36.5
,, 3.	322	1370	751.5	33.5	72	1290	1590.5	36.0
,, 4.	311	500	700	32.8	38	1000	1444.5	36.0
,, 5.	260	630	815	32.5	33	880	1613.0	35.3
,, 6.	234	1450	816	32.5	50	1550	1520.0	36.0
Daily average.	343.5	1275	715.9	33.1	77.2	1408	1467.2	35.8

The contents of dry matter was in these materials as follows :—

Hay ... ... 83.78 %
Residues, Sheep No. I ... ... 82.86 „
„ „ „ II ... ... 81.66 „
Fæces, Sheep No. I ... ... 40.78 „
„ „ „ II ... ... 28.10 „

The chemical analysis of the hay, residues and fæces gave the following results, per cent of dry matter

	Hay.	Residues uneaten.		Fæces.	
		Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
Crude protein	10.82	10.32	9.85	9.84	10.18
Fat...	2.80	2.52	2.38	3.22	3.54
Fibre	42.38	45.33	48.48	35.24	33.55
Nitrogenfree extract	35.69	33.31	30.44	39.19	40.60
Ash	8.31	8.52	8.85	12.51	12.13
Total nitrogen	1.734	1.641	1.576	1.574	1.630
Albuminoid nitrogen	1.633	—	—	—	—

The daily quantities eaten, excreted and digested are calculated as follows:—

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Hay given...............	837.81	768.17	90.67	23.51	355.07	298.93
„ left..................	283.81	259.62	29.30	7.14	128.64	94.54
„ eaten...............	554.00	508.55	61.37	16.37	226.43	204.39
Excreted	291.96	255.42	28.73	9.39	102.89	114.42
Digested..................	262.04	253.12	32.64	6.98	123.54	89.97
Sheep No. II.						
Hay given...............	837.81	768.17	90.67	23.51	355.07	298.93
„ left..................	63.05	57.47	6.21	1.50	30.57	19.19
„ eaten...............	774.76	710.70	84.46	22.01	324.50	279.74
Excreted	412.35	362.31	41.96	14.59	138.35	167.42
Digested..................	362.41	348.39	42.50	7.42	186.15	112.32
Digested in per-cent. Sheep No. I	47.30	49.77	53.51	42.34	54.56	44.01
„ „ II	46.76	49.02	50.03	33.71	57.34	40.16
Average.....	47.0	49.4	51.8	38.2	56.0	42.1

By the composition as well as by the digestibility the fodder from Imperata arundinacea may be characterized as a *"rather poor"* kind of hay, its contents of digestible nutrients being (compare p. 13):

Crude protein	5.60 %
Carbohydrates and fat	41.38 „

IV. Millet Hay (Panicum frumentaceum) (Hiye).

Of the three kinds of millet, Pancium frumentaceum, italicum and miliaceum which are frequently cultivated for grain in this country, only the former species is sometimes cured as hay and is cut for this purpose when the seeds are milk-ripe. With regard to graminæ in general this stage of growth is somewhat too late to obtain good fodders; but as millet differs in many respects from those cereals and grasses, which have already been subjected to digestion trials in various stages of growth, it cannot be said *a priori* that the above rule is also valid for this plant.

We have made at first two trials with millet cured at the period under discussion. One of them was carried out by Mr. *H. Ibara* in the winter of 1882/83 with hay that had been got in well; the other, examined by Mr. *M. Matsuoka* in December 1883, had got several strong rains while curing in the field. It is peculiar that in each of the two years one of the two sheep employed in the experiment got diarrhœa after feeding them on millet hay for several days, and left so considerable remainders in the rack that the trials had to be carried on with the other animal only.

The animals, rams of the Merino breed, received a daily ration of 1 Kilogram of hay and 6 Grams of common salt. In 1882 a small amount of the food was left uneaten which was collected and analyzed. The quantity of fæces and water drunk was as follows (in Grams):—

December.	Trial 1882. Fæces.	Water.	December.	Trial 1883. Fæces.	Water.
12.	929	1817	13.	1431.5	2900
13.	1055	1600	14.	1452.5	2550
14.	1134	1520	15.	1528.5	1050
15.	1253	1540	16.	1526.6	2459
16.	1383	1900	17.	1475.0	1500
17.	1658	1880	18.	1400.0	1750
18.	1609	2230	19.	1590.0	2250
19.	1653	2000	20.	1350.0	1500
Daily average.	1344.25	1823		1469.25	1981

The average live-weight was 39.5 and 50.5 Kilograms resp. in the two years.

The percentage composition of the fodders, remainders and fæces was as follows :—

	Trial 1882. Hay.	Residues.	fæces.	Trial 1883. Hay.	Fæces.
Water	17.14	17.50	77.02	14.46	69.63
In the dry matter:					
Crude protein	11.23	7.72	12.34	11.77	10.69
Fat	1.89	1.18	1.97	2.31	1.74
Fibre	32.34	42.14	30.50	41.85	32.03
Nitrogenfree extract.	45.72	39.91	40.35	34.76	39.58
Ash	8.82	9.05	14.44	9.31	15.96
Total nitrogen	1.807	1.235	2.038	1.886	1.710
Albuminoid nitrogen	1.520	0.840	1.888	1.687	—

From these data the daily consumption, excretion and digestion are calculated in the following :—

	Dry matter. Grams.	Organic matter. Grams.	Crude protein Grams.	Fat Grams.	Fibre Grams.	Nitrogenfree extract Grams.
Trial 1882.						
Hay given...............	828.57	755.49	93.08	15.64	268.00	378.77
„ left..................	40.35	36.70	3.12	0.48	17.01	16.10
„ consumed.........	788.22	718.79	89.96	15.16	250.99	362.67
Excreted.................	306.59	262.32	39.05	6.04	93.51	123.71
Digested..................	481.63	456.47	50.91	9.12	157.48	238.96
„ in percent...	61.10	63.37	61.70	60.16	62.74	65.89
Trial 1883.						
Hay eaten...............	855.42	775.77	100.65	19.73	357.96	297.43
Excreted.................	446.27	375.05	47.69	7.76	142.94	176.65
Digested..................	409.15	400.72	52.96	11.97	215.02	120.78
„ in percent...	47.83	51.66	52.61	60.65	60.07	40.61

The millet hay cured under favourable conditions of weather (1882) is, according to these results an easily digestible fodder with a medium content of protein and having about the same nutritive value as *"medium good"* meadow hay (see p. 12). The specimen examined in 1882, though already in the state of milk-ripeness, contained still a fair amount of albuminoids, and the formation of fibre had not yet advanced very far, whence it seems that late cutting is not so objectionable in the case of this millet, as it has been observed to be with other gramineæ.

A comparison of the two kinds of hay affords a striking illustration of damage caused by wetting while curing. In consequence of the extraction of crude protein and nitrogen-free extract by rain the proportion of crude fibre was about 10 percent higher in the sample injured by rain than in the other hay, and the digestibility had been materially diminished; the contents of digestible nutrients, percent of dry matter are as follows:—

	Without rain.	With rain.
Crude protein	6.93	6.19
Carbohydrates and fat	53.08	42.64

Assuming that in 1883 we might have obtained the same kind of hay, if there had been no rain while curing,—which will be, of course, only approximately true,—we find that of 100 parts of each group of nutrients the following losses had been caused by the rain:

	Raw nutrients.	Digestible nutrients from 100 p. of raw ones.	Loss from 100 p. of digestible nutrients.
Crude protein	19.0	19.1	27.9
Nitrogenfree extract	41.4	42.1	63.9

These figures show, how enormous an amount of nutrients is liable to be lost, unless the utmost care and speed are bestowed upon the curing of the hay. Moreover, the close coincidence of the two first columns indicates that the materials extracted by rain or destroyed by a subsequent fermentation are the most valuable as they are absolutely digestible.

V. Hay of Soy Beans (Karimame).

This hay is considered the best coarse fodder in this country. It is usually cured, when the pods have developed their normal size but the leaves are still green.

A specimen of such hay was examined in 1883 by Mr. *M. Ota.* The two animals (rams), of which No. I was a Merino, No. II a Southdown received per day and head besides 6 Grams of salt, 1 Kilogram of hay, but left some of the food uneaten, which consisted chiefly of the lower hard stems.

The quantity of these remainders, fæces excreted, water consumed and live-weights are contained in the following table:

1883.	Residues in Grams.		Fæces in Grams.		Water in Grams.		Live-weight in Kilograms.	
	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
Nov. 29.	107.2	227.7	613.2	780.7	1700	1685	36.0	26.5
„ 30.	95.9	224.2	811.7	654.7	2170	1850	36.1	27.3
Dec. 1.	107.4	218.5	910.5	732.7	1900	1750	37.0	28.4
„ 2.	100.9	198.9	979.9	875.7	1850	1700	37.6	29.0
„ 3.	78.2	124.5	958.2	808.7	1902	1725	38.3	29.9
„ 4.	71.0	155.8	986.9	739.6	1848	1624	38.5	30.5
„ 5.	92.7	179.5	995.2	780.8	1400	1350	38.9	30.0
„ 6.	78.5	119.5	1011.4	751.2	1694	1813	39.0	30.1
Daily average.	91.5	180.95	908.1	765.5	1809	1687	37.7	29.0

The analysis of the hay, remainders and fæces gave the following results:

	Hay.	Residues. Sheep No. I.	Sheep No. II.	Fæces. Sheep No. II.	Sheep No. II.
Water	16.85	21.36	19.24	60.56	60.23
In the dry matter:					
Crude protein	16.91	8.17	8.61	14.18	15.73
Fat	2.56	1.12	1.40	5.35	5.38
Fibre	42.29	56.93	53.14	40.15	37.11
Nitrogenfree extract.	31.28	25.93	28.87	26.51	29.40
Ash	6.96	7.85	7.98	13.81	12.38
Total nitrogen	2.705	1.307	1.377	2.269	2.516
Albuminoid nitrogen	2.146	1.226	1.199	—	—

The consumption of food, excretion and digestion per day was as follows:

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Hay given...............	831.50	773.62	140.59	21.29	351.65	260.09
„ left..................	70.93	66.29	5.88	0.81	40.95	18.65
„ consumed..........	759.57	707.33	134.71	20.48	310.70	241.44
Excreted..................	330.91	285.20	46.92	17.70	132.86	87.72
Digested..................	428.66	422.13	87.79	2.78	177.84	153.72
„ in percent....	56.44	59.51	65.17	13.54	57.24	63.67
Sheep No. II.						
Hay given...............	831.50	773.62	140.59	21.29	351.65	260.09
„ left..................	150.46	138.45	12.95	2.11	79.95	43.44
„ consumed..........	681.04	635.17	127.64	19.18	271.70	216.65
Excreted..................	304.44	266.75	47.89	16.38	112.98	89.50
Digested..................	376.60	368.42	79.75	2.80	158.72	127.15
„ in percent...	55.30	58.00	62.50	14.12	58.41	58.69
Average digestion coefficients...............	55.87	58.76	63.84	13.83	57.83	61.18

In spite of its high content of fibre the soy bean hay is comparatively highly digestible and, as regards its proportion of digestible nutrients, equals lucerne; it contains:—

Digestible crude protein... ... ... 10.79 %
„ fat ... ... 0.35 „
„ fibre ... ... 24.46 „
„ nitrogenfree extract ... 19.14 „

Another trial was carried out by Mr. *H. Tojo* with soy bean hay cut in full blossom on July 5th of 1886 for the purpose of finding out whether early cutting may be preferable to the usage adopted in practice. The animals employed were both wethers of the Merino breed and the daily ration given consisted per head of 800 Grams of hay and 10 Grams of salt, which were, however, not totally eaten.

The amounts of hay left, fæces and the live-weights are put down in the following table:

1887 May.	Sheep No. I.			Sheep No. II.		
	Hay left. Grams.	Fæces. Grams.	Live-weight. Kilog.	Hay left. Grams.	Fæces. Grams.	Live-weight. Kilog.
9.	116.5	626	34.8	37	942	33.1
10.	123	720	34.7	53.5	1149	33.2
11.	125	622	34.7	87.5	862	33.2
12.	107	690	34.5	79	991	33.2
13.	129	761	34.4	86.5	1109.5	33.2
14.	63	686	34.6	100	872	32.8
15.	98	736	34.4	49	969	32.6
16.	114	786	33.9	114	786	33.2
Daily average	109.44	703.4	—	75.8	960.1	—

The percentage composition of the hay, remainders and fæces was as follows:

	Hay.	Remainders.	Fæces. Sheep No. I.	Fæces. Sheep No. II.
Water	13.5	15.50	65.34	74.32
In the dry matter:				
Crude protein	18.42	9.20	11.95	13.18
Fat	3.64	1.76	5.02	5.32
Fibre	37.58	63.12	44.36	43.75
Nitrogenfree extract.	33.63	18.91	26.44	26.05
Ash	6.73	7.01	11.93	11.70
Total nitrogen	2.947	—	—	—
Albuminoid nitrogen	2.63	—	—	—

The daily consumption of food, excretion and digestion is calculated as hereafter :—

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Hay given	692.00	645.43	127.47	25.19	260.05	332.72
,, left	92.55	86.06	8.51	1.63	58.42	17.50
,, consumed	599.45	559.37	118.96	23.56	201.63	215.22
Excreted	243.80	214.71	29.13	12.24	108.88	64.46
Digested	355.65	344.66	89.83	11.32	92.75	150.76
Sheep No. II.						
Hay given	692.00	645.43	127.47	25.19	260.05	232.72
,, left	63.99	59.50	5.90	1.13	40.39	12.10
,, consumed	628.01	585.93	121.57	24.06	219.66	220.62
Excreted	247.51	218.55	32.62	13.17	108.29	64.48
Digested	380.50	367.38	88.95	10.89	111.37	156.14
Digestion coefficients:						
Sheep No. I	59.33	61.61	75.51	48.04	46.00	70.05
,, ,, II	60.58	62.69	73.17	45.26	50.70	70.77
Average	59.96	62.15	74.34	46.65	48.35	70.41

As these results show, the early cut soy bean hay is richer in crude protein, fat and nitrogenfree extract, but poorer in fibre and accordingly also more digestible than that which is cured when the pods are out. It contains, percent of dry matter:

Digestible crude protein	... ...	13.69 %
,, fat	... ...	1.70 ,,
,, fibre	... ...	18.16 ,,
,, nitrogenfree extract	...	23.68 ,,

Although a better and more digestible fodder can be obtained by cutting earlier than it is at present the custom to do, it cannot be recommended to cure the soy beans before they have completed the growth of the pods, because as a very important practical fact the quantity of dry matter increases still very considerably after the flowering period of that plant. At an investigation which we made on another occasion we observed that the total dry matter of

a whole soy bean plant in full blossom was only 7.45 Grams, while at fully developed pods, but still far from being ripe it weighed about three times as much, viz. 22.10 Grams. Hence experience has guided the farmers of this country in the right direction in this case.

VI. Straw of Paddy and Upland Rice.

A specimen of *paddy rice straw* harvested on November 9th, 1885 in a rather overripe state was examined as to its composition and digestibility by Mr. *M. Kaneko* toward the end of the same month. The sheep employed were both wethers of the Southdown breed, about three years old. A small ration, only 600 Grams with 10 Grams of common salt per day and head was given in the experiment, in order to have the food consumed as completely as possible, moreover, to prevent the animals from picking out only the most palatable parts, as panicles and leaves, the straw was chopped into lengths of about $1^1/_2$ centimeters. The whole amount for the trial had been cut and well mixed before the experiment was commenced. Sheep No. II consumed its ration, indeed, almost completely, while the other animal had not much appetite for the straw and excreted very soft fæces.

The proportions of straw left uneaten, the weight of the fæces and the live-weights are compiled in the following table :

November 1885.	Sheep No. I.			Sheep No. II.		
	Straw left Grams.	Fæces. Grams.	Live-weight. Kilog.	Straw left. Grams.	Fæces. Grams.	Live-weight Kilog.
24.	42.5	595.5	42.1	11.0	486.0	37.6
25.	18.0	526.0	41.8	8.0	433.0	37.9
26.	38.0	505.0	41.8	0.7	344.0	37.6
27.	54.5	1270.5	41.6	2.0	591.0	37.3
28.	47.5	1088.5	40.6	3.5	785.5	37.1
29.	111.0	1431.0	40.0	1.0	612.5	36.8
30.	51.0	1320.5	40.0	.0	626.0	36.8
Dec. 1.	3.0	1054.0	39.4	0.5	675.0	37.3
Per day	45.75	973.88	—	3.34	566.88	—

There were the following contents of water in the food, residues and fæces :

Straw	79.21 °/₀
Residues left by Sheep No. I...	74.64 „
Fæces of Sheep No. I	72.97 „
„ „ „ „ II	55.71 „

The composition per cent. of these materials free from water was stated herewith :—

	Straw.	Straw left.	Faeces. Sheep No. I.	Faeces. Sheep No. II.
Crude protein	6.80	5.53	6.27	6.77
Fat	2.17	0.84	2.41	2.22
Fibre	48.68	52.37	36.21	36.09
Nitrogenfree extract.	24.80	22.54	28.18	29.04
Ash.	17.55	18.72	26.93	25.88
Total nitrogen... ...	1.088	18.85	—	—
Albuminoid nitrogen.	0.88	0.80	—	—

The consumption, excretion and digestibility of the constituents of the hay are calculated on the basis of the data given, as follows :

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Sheep No. I.						
Straw given	475.26	391.85	32.32	10.31	231.36	117 86
„ left	34.15	27.26	1.89	0.29	17.88	7.70
„ consumed	441.11	364.59	30.43	10.02	213.48	110.16
Excreted	263.24	192.35	16.51	6.32	95.32	74.20
Digested	177.87	172.24	13.92	3.70	118.16	35.96
„ in percent of each component...	40.55	47.24	45.68	36.93	55.35	32.66
Sheep No. II.						
Straw consumed	475.26	391.85	32.32	10.31	231.36	117.86
Excreted..................	251.06	186.10	17.00	5.57	90.62	72.91
Digested	224.18	205.75	15.32	4.74	140.74	44.95
„ in percent of each component...	47.17	52.51	47.40	45.97	60.84	38.15
Coefficients in average of the two trials...	43.86	49.88	46.54	41.45	58.10	35.41

Researches on a sample of *upland rice straw,* grown on the farm of this college, were made at the same time by Mr. *H. Kamoshita.* The animals, No. I a Merino, No. II a Southdown, both wethers received per day and head 750 Grams of chopped straw, 7 Grams of common salt, and water ad libitum; but both consumed only a part of the straw given.

The amount of residues left, fæces ejected and the live-weights are put down in the following table :

November 1885.	Sheep. No. I.			Sheep No. II.		
	Straw left. Grams.	Fæces. Grams.	Live-weight. Kilog.	Straw left. Grams.	Fæces. Grams.	Live-weight. Kilog.
20.	41.5	913.0	3.75	272.2	432.0	21.8
21.	36.0	713.3	38.0	333.5	532.0	22.5
22.	185.5	1097.5	37.0	335.0	508.0	21.7
23.	161.0	972.5	37.5	388.5	463.1	21.5
24.	184.5	1050.0	37.0	416.9	467.0	21.0
25.	364.5	584.0	36.5	380.0	394.7	21.0
26.	297.5	867.5	35.5	435.0	384.5	21.0
27.	149.5	877.5	36.0	303.0	408.5	20.9
Per day	177.5	884.51	36.8	357.9	448.73	21.4

Food, residues and fæces contained the following proportions of water :

Straw	10.33 %
Residues, Sheep No. I. ...	14.00 „
„ „ „ II. ...	13.01 „
Fæces, Sheep No. I.	65.29 „
„ „ „ II.	50.35 „

The composition precent of the dry matter in these materials was as stated hereafter :

	Straw	Residues Sheep No. I.	Residues Sheep No. II.	Fæces Sheep No. I.	Fæces Sheep No. II.
Crude protein... ...	6.75	6.42	6.57	6.20	6.50
Fat	2.16	2.02	1.88	1.79	1.86
Fibre	40.35	39.26	40.68	30.80	28.68
Nitrogenfree extract	32.14	35.20	33.46	36.66	36.11
Ash.	18.60	17.10	17.42	25.54	26.85

The following calculation contains the quantities of single nutrients consumed and ejected and the percentage digestibility :

	Dry matter Grams.	Organic matter Grams.	Crude protein Grams.	Fat Grams.	Fibre Grams.	Nitrogenfree extract Grams.
Sheep No. I.						
Straw given	672.52	547.45	45.40	14.52	271.38	216.15
„ left	152.72	126.61	9.80	3.09	59.96	53.76
„ consumed	519.80	420.84	35.60	11.43	211.42	162.39
Excreted	307.28	231.84	19.05	5.50	94.64	112.65
Digested..................	212.52	189.00	16.55	5.93	116.78	49.74
„ in percent of each component...	40.88	44.99	46.49	51.88	55.24	30.62
Sheep No. II.						
Straw given	672.52	547.45	45.40	14.52	271.38	216.15
„ left	316.27	261.19	20.78	5.93	128.66	105.82
„ consumed	356.25	286.26	24.62	8.59	142.72	110.33
Excreted	222.75	162.93	14.48	4.13	63.88	80.44
Digested..................	133.50	123.13	10.14	4.46	78.84	29.89
„ in percent of each component ...	37.47	43.07	41.19	51.92	55.24	27.09
Coefficients in average of the two trials...	39.18	44.03	43.84	51.90	55.24	28.86

According to these researches both paddy and upland rice straw are *good fodders,* for straw of their nature. They are comparatively rich in protein and at least as easily digested as other kinds of cereal straw. This is proved by a comparison of our results with those obtained in similiar experiments with ruminants in Germany. The composition per cent. of various sorts of straw and the coefficients of digestibility, taken from Wolff's compilations are the following :

Kind of Straw.	Crude protein.	Fat.	Fibre.	Nitrogenfree extract.	Ash.	Digestible nutrients.		
						Crude protein.	Carbo-hydrates	Fat.
Wheat	5.2	1.1	47.7	39.8	6.2	0.9	41.9	0.4
Rye............	4.4	1.4	46.2	43.1	5.3	0.9	43.4	0.5
Barley	4.8	2.5	42.0	44.7	5.9	1.0	47.5	1.0
Oat............	6.8	2.3	42.0	42.0	7.5	2.8	44.1	0.7
Paddy rice...	6.8	2.2	48.7	24.8	17.5	3.2	36.1	0.9
Upland rice.	6.7	2.2	40.4	32.1	18.6	3.0	31.6	1.1

Coefficients of digestibility.	Crude protein.	Fat.	Fibre.	Nitrogen-free extract.	Organic matter.
Wheat	16.9	35.6	55.5	38.7	46.3
Rye	21.0	31.9	59.8	36.6	46.4
Barley	20.0	41.6	55.5	54.1	52.7
Oat	40.7	30.1	59.6	45.5	51.3
Paddy rice..................	46.5	41.5	58.1	35.4	49.9
Upland rice	43.8	51.9	55.2	28.9	44.0

The paddy rice straw of our experiments had been unfortunately cut rather late, as already stated, which is also shown by the high proportion of fibre. In spite of this unfavorable condition it proved to be still a little richer in digestible nutrients than the upland rice straw. The question as to which of the two kinds of rice straw is better for feeding is accordingly answered in favour of the paddy rice, which result is in harmony with practical experience.

B. Concentrated Feeding Stuffs.

Owing to the organization of their digestive organs, the ruminants cannot be safely fed for a period of several weeks with concentrated feeding stuffs only. Their ration must contain some coarse fodder. In experiments on the digestibility of the former class of feeding stuffs they must consequently be given in mixture with a coarse fodder of known digestibility. Generally in the first period the digestibility of the coarse fodder is determined, when fed alone and in the second period a certain amount of the concentrated fodder is added and the digestibility of the mixture is determined. As those kinds of the latter class of feeding stuffs which contain a medium proportion of crude protein, do not essentially alter the digestion of the former class, the two feeding periods usually yield results which admit of calculating the digestibility of the concentrated fodder accurately enough for practical objects. The methods for keeping and feeding the animals and for collecting the fæces during the two periods were in our researches, of course, the same as in the trials on coarse fodders already described (p. 3—6).

I. Rice Bran (Nuka).

The rice bran is a refuse material obtained in the process of "polishing" or "whitening" the grains previously freed from the chaff. It consequently consists only of the

superficial layers of the grains mixed with some broken pieces or powder of whole grains. The quantity of bran obtained from 100 p. of the raw seeds is not great, amounting only to 7-8 percent, as it is shown by the following trials made by students of our college with the help of the common wooden hammers and mortars; there resulted from 100 p. of raw rice :—

	Rice from Mino.	Rice from Echiu.
Whitened rice	91.05	91.92
Bran...	7.37	7.16
Broken grains, etc	1.69	0.59
	100.11	99.67

Numerous analyses made in Europe have already proved that the rice bran is a very nutritious fodder rich in albuminoids and fat and particularly suited for the feeding of milk cows and for fattening. Researches on the digestibility have, however, not yet been made.—In Japan these brans, like so many other materials of a high feeding value, are still widely applied directly as manure, instead of utilizing them first as food for domestic animals and thereby increasing the manurial effect.

The digestibility of a specimen of rice bran was determined in 1884 by Mr. *S. Kakizaki*, who supplied rams of the merino breed per day and head with a ration of 750 Grams of common hay, 250 Grams of bran and 6 Grams of salt, which was completely consumed. The hay given had been examined in a preceding experiment (described p. 9) as to its composition and digestibility.

The quantity of fæces ejected, water drunk and the live-weights, as observed in the main period, were as follows :—

January. 1884.	Fæces. Grams.		Water. Grams.		Live-weight. Kilograms.	
	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
21.	1265.7	1020.0	—	2450	38.4	38.4
22.	1115.2	742.0	2600	1550	38.0	38.0
23.	1358.7	926.0	2580	1740	37.5	38.2
24.	1186.7	1077.2	3150	1350	37.7	38.2
25.	1103.4	983.2	2720	1330	37.7	28.2
26.	1300.8	1020.0	2530	1340	37.3	37.5
27.	1217.8	939.0	3150	1670	37.2	37.2
28.	1141.8	893.0	3650	1880	37.0	37.5
Daily average.	1211.26	950.05	2910	1910	37.6	37.9

The analysis of the bran and the fæces gave the following results, percent :—

	Rice bran.	Fæces.	
		Sheep No. I.	Sheep No. II.
Water	12.44	75.40	69.29
In the dry matter:			
Crude protein	16.82	13.13	13.08
Fat	19.07	4.83	5.37
Fibre	10.26 [1])	27.00	26.28
Nitrogenfree extract ...	43.43	38.09	37.94
Ash	10.31	19.95	16.83
Total nitrogen	2.692	—	—
Albuminoid nitrogen ...	2.254	—	—

With the help of the data just given and the numbers formerly obtained for the composition and digestibility of the hay, the digestibility of the rice bran is calculated as hereafter :—

[1]) Free from ash only; the nitrogen could not be determined owing to the small amount of raw fibre obtained in the analysis.

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fibre. Grams.	Fat. Grams.	Nitrogenfree extract. Grams.
Consumed: Bran	218.91	196.35	36.83	41.75	22.46	95.31
„ Hay	624.26	567.14	76.41	19.35	207.26	264.13
„ Total	843.17	763.49	113.24	61.10	229.72	359.44
Sheep No. I.						
Excreted	297.95	247.45	39.14	14.39	80.44	113.48
Digested of the bran and hay	545.22	516.04	74.10	46.71	149.28	245.95
Digested of the hay alone	362.32	324.76	46.11	9.25	135.44	151.95
Digested of the bran alone	182.90	173.28	27.99	37.46	13.84	94.00
Digested percent of the components of the bran	83.55	88.25	76.00	89.72	62.05	98.62
Sheep No. II.						
Excreted	291.81	242.56	38.16	15.68	77.99	110.74
Digested of the bran and hay	551.36	520.93	75.08	45.43	151.73	248.70
Digested of the hay alone	362.32	342.76	46.11	9.25	135.44	151.95
Digested of the bran alone	189.04	178.17	28.97	36.28	16.29	96.74
Digested percent of the components of the bran	86.31	90.24	78.66	86.89	72.53	101.63
Digestion coefficients, average	84.93	89.25	77.33	89.31	67.29	100.08

According to these results the rice brans are a very digestible food rich in available nutrients and surpassing in this respect all other kinds of cereal bran. Our sample contained in 100 p. of dry matter the following quantities of digestible nutrients :—

Crude protein...	13.01
Fat	16.84
Fibre	43.43
Nitrogenfree extract.	6.90

Admixtures of broken grains and meal of the interior

part of the grains will not interfere with the digestibility, as according to researches by Meissl and Strohmer[1]) 98.5°/₀ of the total dry matter and 88.6°/₀ of the crude protein of the polished rice are digested by swine and according to K. Osawa men extract an equally high amount, viz. 97.5°/₀ of the dry matter and 80.1°/₀ of the crude protein.

There is, however, another thing that might sometimes prevent the feeder from using rice bran, it is the admixture of earthy materials which are very frequently resorted to for facilitating and accelerating the process of polishing. The resulting bran then contains about 20°/₀ of ash, half the proportion of which is made up by the admixture. Besides these deteriorations direct adulterations consisting of admixtures of sand, earth and other materials seem not to be rare; we have found as much as 60°/₀ of foreign substances in marketable rice bran.

II. Soy Bean (Daizu).

Although the soy beans are somewhat expensive owing to their principal utilization as human food (tofu, miso and shoyu), it may happen that small proportions of them are resorted to in the feeding of the live-stock, for the purpose of supplementing the protein of a ration otherwise to poor in that nutrient.

The animals employed in the trials which were carried out by Mr. *K. Ogasawara,* were rams, No. I a Merino, No. II. a Southdown. The ration given per day and head consisted of 250 Grams of soy beans, 6 Grams of salt and 750

---

1) Transactions of the Vienna Academy of Sciences, 1883, July.

grams of the same kind of hay as used in the experiment on the digestibility of rice bran. It was totally consumed throughout the whole trial.

The quantity of fæces ejected, water drunk and the live-weights were as follows :—

January.	Fæces. Grams.		Water. Grams.		Live-weight. Kilograms.	
1884.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
21.	1220.3	1320.8	—	—	34.0	33.7
22.	1202.3	1214.8	1750	3010	35.3	35.0
23.	1108.4	1068.7	1850	2290	35.2	35.0
24.	992.4	1144.9	2100	1900	35.3	35.2
25.	1000.4	1005.8	1650	2165	35.4	35.0
26.	905.4	1156.8	1850	1850	35.2	35.1
27.	998.5	996.4	1700	1950	35.4	35.1
28.	912.3	1173.4	1700	1950	35.4	35.0
Daily average.	1042.5	1135.2	1800	2160	35.2	35.1

The percentage composition of the beans and fæces was found to be as hereafter :—

	Beans.	Fæces.	
		Sheep. No. I.	Sheep. No. II.
Water	11.88	—	—
In the dry matter :—			
Crude protein	39.33	13.74	13.83
Fat	19.36	4.12	4.27
Fibre	5.40	21.60	21.46
Nitrogenfree extract	31.60	46.57	46.12
Ash	4.31	14.41	14.32
Total nitrogen	5.544	—	—
Albuminoid-nitrogen	5.514	—	—

From the data hitherto given the consumption, excretion and digestion is calculated as herafter :—

	Dry matter. Grams.	Organic matter. Grams.	Crude protein. Grams.	Fat. Grams.	Fibre. Grams.	Nitrogenfree extract. Grams.
Consumed: Hay........	624.26	567.14	76.41	19.35	207.25	264.13
„ Soy beans	220.30	210.80	86.63	42.65	11.91	69.61
„ Total......	844.56	777.94	163.04	62.00	219.16	333.74
Sheep No. I.						
Excreted	296.29	253.58	40.70	12.20	62.69	137.99
Digested..................	548.27	524.36	122.34	49.80	156.47	195.75
„ from the hay	362.32	342.76	46.11	9.25	135.44	151.95
Digested from the beans..................	185.95	181.60	76.23	40.55	21.03	43.80
Digested in percent...	84.41	86.15	87.79	95.08	176.58	62.92
Sheep No. II.						
Excreted	301.41	258.26	41.70	12.88	64.67	139.02
Digested..................	543.15	519.68	121.34	49.12	154.49	194.72
„ from the hay	362.32	342.76	46.11	9.25	135.44	151.95
Digested from the beans..................	180.83	176.93	75.23	39.87	19.05	12.77
Digested in percent...	82.08	83.93	86.64	93.48	160.00	61.44
Average Digestion coefficients..............	83.25	85.04	87.22	94.28	168.29	62.[illegible]

The digestibility expressed by these results coincides in general with that observed in experiments on similiar leguminous seeds. As already found with lupines by Stohmann[1]) and myself[2]) and also with fish meal by myself,[3]) certain concentrated feeding stuffs rich in protein seem to favour the dissolution resp. fermentation of the crude fibre *of the coarse fodder* in the digestive canal and, according to the above digestion coefficients (176.6 resp. 160.0) obtained for the crude fibre the soy beans seem to have the same effect. After all, this appears not to be a very rare property of concentrated, nitrogenous fodders, since the tables compiled by E. von Wolff showing the results of digestion

1) Transactions of the agricultural institution of the university at Leipzig, 1875, p. 86.

2) Landw. Jahrbücher, 1880, p. 990.

3) Landw. Versuchsstat. Vol. 20, 1877, p. 423.

experiments, illustrate similiar facts in the case of linseeds and field beans, the crude fibre of which is represented to have been digested to 120.5 resp. 92 percent, although when feeding these materials to ruminants the hulls, which contain the majority of the fibre, are ejected in the fæces apparently without having undergone any considerable alteration in the intestines.

The specimen of soy beans examined by us contains the following proportions of digestible nutrients, percent of the dry matter:—

Crude protein...		34.30
Fat		18.25
Fibre	9.09	28.74
Nitrogenfree extract	19.65	

Of all raw vegetable products, earth nuts perhaps excepted, the soy beans are the richest in the most valuable nutrients: protein and fat, and contain them in a highly digestible form.

The preceding investigations are far from claiming to represent anything like a complete knowledge of the feeding stuffs of this country. They have been merely undertaken chiefly to train a number of students of our college in the methods of experimental research in the hope that they may accomplish what time and opportunity refuse to us at present. Nevertheless, the number of trials being not inconsiderable, some general conclusions may be drawn from an examination of our results.

In her present condition of agriculture, Japan is very poor in good kinds of coarse fodders, especially hay. The flora on the uncultivated land (hara) is composed of long-stalked harsh grasses (Eulalia and Imperata, frequently also low kinds of Bambusa) with only a sparse admixture of leguminous plants. Short soft grasses and nutritious papilionacea are hardly met with to a notable extent in central Japan on those places where cattle farms and horse raising establishments have been or can be founded. The grasses produced there at present may suffice during the warm part of the year for the adult animals, which, wandering over a large area, may pick up the most nutritious parts of the vegetation, but in winter, when, as is usual, concentrated fodders are not procurable, or too expensive, the poor hay made in those places, which has hardly the value of good fodder straw, is not capable of keeping the animals in a good condition. In the towns and villages the animals are not in a much better situation, as forage crops are almost unknown to the Japanese farmers.

A good food is the principal factor, not only in improving a breed but also in maintaining good breeds. Thus, if the offspring of the imported animals are not supplied with suitable fodders they will soon degenerate. Under the present conditions of food raising in Japan it is quite impossible to improve the indigenous breed and still more fruitless will be the task to maintain the foreign, highly

developed breeds. Even the native breeds are not healthy under the present system of feeding. According to information kindly furnished by Prof. Janson of our college, it is an exception to find a horse free from chronic catarrhalic affection of the intestines, among those supplied here to the dissecting room; while, according to his observations in the veterinary college at Berlin, it is a rare occurence there, if among a hundred horses a single one has that disease, which, as a rule, owes its origin to bad food.

If the raising of cattle and horses is to attain the level of other countries, the improvement of the coarse fodders has to be aimed at, first of all. Forage crops must then occupy a part of the fields, or they must be cultivated on the present waste land, and in either case they will be of great benefit to the agriculture at large. Clover, lucerne and other deep-rooted perennial leguminous crops deserve particular attention, because on account of their properties of chiefly feeding on the nutrients of the deeper layers of the soil and of assimilating free nitrogen, they constantly increase the stock of fertilizing ingredients in the farm, and are thus a treasure, hitherto unknown to the Japanese farmer. They are, indeed, totally absent from the list of crops cultivated here at present, but this is by no means due to their not thriving well in this country. Their absence is merely a consequence of the slight attention hitherto paid to the raising of live-stock. If properly cultivated, on a soil well cleaned, and supplied before sowing with some manure, excellent crops are produced. Besides this also among the indigenous wild papilionaceæ some are likely to occur, which may well return the expenses for an experimental cultivation, as I have pointed out on another occasion.—Large crops are furthermore obtained from the majority of the other forage plants, especially from fodder maize; but these may require too much manure in the present very exhausted condition of soils.

With reference to the concentrated feeding stuffs the feeder is already now in a fortunate situation, if he pleases so to be. A long list of excellent grains, oilcakes, brans etc. which as yet are fed to but a small extent, await a utilization as food.

Carl H. Clar...

東京農林學校

學術報告

第三號

Imperial College

OF

AGRICULTURE & DENDROLOGY.

Komaba, Tokyo, Japan.

Bulletin No. 3.

Researches
on the Composition, Treatment, and Application of
Night-soil as a Manure

AND

on the Valuation of Japanese Fertilizers.

BY

Dr. O. Kellner,
Professor of Agricultural Chemistry.

明治廿一年十一月

TOKYO, JAPAN, NOVEMBER, 1888.

PRINTED BY "SEISHI BUNSHA,"
No. 1. Kabu ... bashiku, Tokyo.

Researches on the Composition, Treatment, and Application of Night-soil as a Manure.

By

Dr. O. Kellner and **Y. Mori.**

(Communicated by the Former.)

Night-soil is a mixture of human fæces and urine, of which the former consist for the most part of remnants of food, which are either indigestible or escape digestion, and are ejected in company with a slight proportion of digestive secretions from the body, mucilaginous substances, a few epithelial cells from the intestines, and numerous minute fungi, the sporules of which enter the alimentary canal along with the food, germinate in the intestines and cause putrefaction before the fæces leave the body. The urine, on the other hand, contains, besides a variety of soluble salts, only organic compounds, which are either produced by the decomposition of substances resorbed and assimilated from the food, or which result, in the case of complete or partial hunger, from the consumption of ingredients of the body. It is a secretion separated from the blood in the kidneys by a process similar to filtration or diffusion, whence it is not much infected with germs of fungi, and is not in a putrid condition when it leaves a healthy organism.

Adults are generally quite in equilibrium with what they eat, e. g., the elements taken in as food and by respiration are again entirely given out in the ex-

creta, by exhalation or transpiration, after having served for the production of the energy and heat necessary for the vital functions of the organism. In general, only children and convalescent persons retain certain parts of the resorbed nutrients, depositing them in the growing organs.

The products of the oxidation and decomposition of the digested substances are continually ejected, any accumulation of these in the tissues of the body causing disease and death. The majority of the carbon is exhaled in the form of carbon dioxide through the lungs, an inferior proportion only passes through the skin, while almost all the nitrogen reappears in the urine chiefly as urea, but to a small extent as uric acid and other compounds; of the mineral substances of the food the greater part, especially those which are soluble in water, pass into the urine along with a large quantity of water, the rest into the fæces. As a whole the excreta contain, in the case of adults, all the nitrogen and mineral matters of the food, and are distinguished from the latter particularly by the low proportion of organic substances; at earlier stages of life some of the nitrogenous and mineral substances of the latter, particularly phosphoric acid and lime, are laid down in the body.

Thus the excreta, if properly collected, contain nearly all the fertilizing ingredients of the food; and, owing to the deep disintegration the albuminoids have undergone during their passage through the body, are in a state highly fitted for feeding plants. If in most countries of Europe and America they are not largely resorted to as a manure, this is simply because of the great dilution of the vegetable nutrients contained in them, which so greatly influences the cost of transportation that the same amount of nutrients of equal or higher efficacy and in a very handy shape can be generally obtained in the form of concentrated commercial fertilizers (ammoniacal salts, nitrate of soda, phosphates,

etc.) at cheaper rates than the mere expense of transporting the night-soil to the farm. In Japan, however, the extensive application of the excreta in agriculture is well justified at present, and will probably continue to be so for a long time to come.

As the contents of the fæces and urine in fertilizing ingredients are entirely dependent on the food, and as the ordinary Japanese diet differs in many respects from that of other countries, it appeared to us very desirable to examine the *composition of the excreta of various classes of the Japanese people*, a subject on which not a single analysis has hitherto been made.

We consequently collected specimens from different places in and round Tōkyō, taking usually large samples from several houses, mixing them and drawing an average specimen from that mixture for analysis. The excreta thus examined in our laboratory were of the following descriptions:

1.) Fæces and urine of *farmers* in the neighbourhood of the city, which were analyzed separately. In calculating the composition of the total dung, we assumed that the proportion between urine collected in special urinals and of fæces deposited with some urine in the closets is about 4 : 1.

2.) *Citizens'* night-soil, a complete mixture of the solid and fluid excreta collected from boats, which carry the dung from Tōkyō into the country.

3.) Night-soil from the houses of *middle class officials* collected in the college.

4.) Night-soil from *soldiers* and *students* of the naval college in Tōkyō, who are supplied with a diet, which, containing a moderate quantity of meat, resembles that of Europeans.

The results of the analyses, which were all made by

Mr. *Y. Mori*, assistant in the laboratory, gave the following results, per mille of the fresh dung :—

	1. Farmers' dung.	2. Citizens' night-soil.	3. Middle class officials' night-soil.	4. Soldiers' & students' dung.
Water	952.9	953.1	945.1	944.1
Organic matter	30.3	31.8	38.9	40.7
Ash	16.8	15.1	16.0	15.2
Nitrogen	5.51	5.85	5.70	7.96
Potash..	2.95	2.88	2.40	2.07
Soda	5.10	4.09	4.48	3.61
Lime	0.12	0.19	0.19	0.29
Magnesia..	0.34	0.46	0.60	0.51
Ferric oxide and alumina.	0.26	0.18	0.61	0.61
Phosphoric acid	1.16	1.33	1.52	2.97
Sulphuric acid	0.71	0.35	0.48	0.72
Silica and sand	0.35	1.04	1.10	0.37
Chlorine	7.04	5.50	6.06	5.08
Sodium chloride..	11.60	9.06	9.99	8.37

Comparing the value of these 4 kinds of excreta and taking the content in nitrogen, phosphoric acid, and potash, as the measure for our valuation, we find that the dung of the farmers, who live almost entirely on vegetables even in the neighbourhood of the city, ranks lowest, and that of the soldiers and naval students, who enjoy a food resembling European diet, is the richest, while that of the citizens and middle class officials is only a little better than the farmers' night-soil. There will be no appreciable error, if we take the average calculated from the first three classes as representing the general composition of the excreta ejected from Japanese diet, because the food supplied to the students and soldiers is exceptional, and, with regard to its richness, far surpasses that which is eaten by the Japanese people at large. For the sake of comparison we add to these average

figures the composition of excreta[1], as given by E. von Wolff for Europeans:

In 1000 parts of the fresh excreta:	Excreta of Japanese.	Excreta of Europeans.
Water	950	935
Organic matter	34	51
Ash	16	14
Nitrogen	5.7	7.0
Potash	2.7	2.1
Soda	4.6	3.9
Lime	0.2	0.9
Magnesia	0.5	0.6
Ferric oxide and alumina	0.3	—
Phosphoric acid	1.3	2.6
Sulphuric acid	0.5	0.5
Silica	0.5	0.2
Chlorine	6.2	4.0
Common salt	10.2	6.6

According to these figures the night-soil from people living on ordinary Japanese food is more dilute than the excreta resulting from a mixed European diet, as is also shown by the composition of the dung of students and soldiers (No. 4 of the table on p. 4). From purely vegetable nutrition the fæces are generally richer in water than from a mixed diet, the quantities daily excreted by an adult varying from 53 to 1670 grms.[2] according to the larger or smaller amount of foods of animal origin (meat, eggs, fish, etc.) consumed. Moreover, the high proportion of common salt taken in by Japanese in the shape of salted vegetables, *miso* and *shoyu*, increases the volume of the urine

1) The night-soil collected in the closets in Europe is usually very dilute owing to the custom of pouring refuse water from kitchens etc., into it. Hence we cannot take its composition as a standard of comparison with our results, but are compelled to resort to the figures given for the entirely fresh state of the excreta quantitatively collected for physiological researches.

2) C. von Voit, Physiologie der Ernährung, 1881, p. 484.

and thus diminishes also the concentration of the whole dung. Eliminating the degree of dilution by calculating how much of the principal fertilizing compounds is contained in the night-soil for every 100 parts of nitrogen we get the following figures:—

	Phosphoric acid	Potash	Lime	Common salt
From ordinary Japanese diet	22.8	47.4	3.5	175.3
„ foreign styled food ...	37.3	25.9	3.6	108.4
„ European diet	37.1	30.0	12.9	94.2

Here we see that the excreta of the common people in Japan contain considerably less phosphoric acid and lime, but more potash and sodium chloride for a given amount of nitrogen, than European night-soil does. As the relative proportion of the fertilizing ingredients has to be seriously taken into account in manuring the crops, we shall have to reflect again on this fact in a later part of this paper.

As urine and fæces are also applied sometimes separately, we have again analyzed the following specimens:

1.) *Fæces* mixed with some urine, as they are collected in closets apart from urinals. This sample represents the average obtained by mixing equal quantities of the dung from several houses of *Farmers* round Tokyo.
2.) *Farmers' urine,* a mixture from the urinals of the same places, whence specimen No. 1 was taken.
3.) *Citizens' urine,* collected from several public and private urinals in Tokyo.

The researches gave the following results to which we may add the composition of the fæces and urine as given by E. von Wolff for European conditions:—

In 1000 parts of the fresh substance:	Fæces of farmers.	Urine of farmers.	Urine of citizens.	Foreign excreta	
				fæces.	urine.
Water	885.8	969.7	967.7	772	963
Organic matter	95.8	14.0	18.6	198	24
Ash	18.4	16.3	13.7	30	13
Nitrogen	10.37	4.29	5.70	10.0	6.0
Potash	3.39	2.84	1.37	2.5	2.0
Soda	3.23	5.57	5.23	1.6	4.6
Lime	0.5	0.03	0.04	6.2	0.2
Magnesia	1.70	0.02	trace.	3.6	0.2
Ferric oxide and alumina	1.28	trace.	0.01	—	—
Phosphoric acid	3.60	0.55	0.44	10.9	1.7
Sulphuric acid	0.49	0.77	0.96	0.8	0.4
Silica and sand	1.26	0.12	0.07	1.9	—
Chlorine	3.70	7.88	6.93	0.4	5.0
Sodium chloride	6.10	12.98	11.42	0.66	8.24

The composition of the dung collected from the closets of farmers cannot be strictly compared with that of the contents of the unmixed fæces of Europeans, as the proportion of urine ejected along with the former is pretty considerable, amounting to almost half the quantity of the closet dung. In accordance with what has been stated with regard to the whole of the excreta from Japanese diet, the above analyses show, especially in the case of the urine, that it is somewhat dilute, as compared with the urine of Wolff's compilations, and in relation to the nitrogen, poor in phosphoric acid and lime. In all specimens of the excreta examined, resulting from Japanese food, potash and common salt are present in larger proportions than in those examined in Europe. This fact seems to corroborate the hypothesis of Bunge[1], according to which the potash salts of the food have an influence on the excretion

1) Zeitschrift für Biologie, vol. 9, 1873, p. 104 and vol. 10, 1874, p. 111.

of sodium, in that the more potash is consumed, the more soda appears in the excreta. As a consequence thereof, says Bunge, people whose diet includes much vegetable food which is generally rich in potash, necessarily consume a comparatively high quantity of common salt to replace the loss of soda. Now the ordinary Japanese diet is, indeed, largely made up of vegetables rich in potash, such as roots, tubers, young legumes, and tea, and thus creates a predilection for salted foods (*miso, shoyu,* and vegetables, especially raddishes, pickled in salt water).

Experience has taught the Japanese farmer not to apply human excreta in the fresh state to his crops, but to allow the manure to undergo a thorough *putrefaction* or *fermentation* before it is used. For this purpose it is diluted with a 2–3 fold volume of water and kept in large wooden tubs for about 10 days during the cold part of the year, and for about 5–6 days during the warm season. When a greenish colour makes its appearance on the surface of the dung, the decomposition is regarded as complete, and the manure is then ready for application. During this period of putrefaction and fermentation of the diluted night-soil, as well as while storing unmixed excreta before using them, a deep disintegration of the organic ingredients is effected by the vigorous growth and enormous increase of the minute fungi which are contained in the fæces and enter the excreta along with atmospheric dust; a considerable proportion of the organic substance is destroyed, escaping into the air, in the form of carbon dioxide and marsh gas; the urea, the principal nitrogenous constituent of the urine unites with water, and is converted into ammonium carbonate; and, in consequence, the reaction of the urine, which is acid when it leaves the body, turns alkaline; owing to this latter change, various substances of the fæces, especially biliary products are dissolved, and confer a dark brown or greenish colour on the dung.

As the carbonate of ammonia which so copiously originates in the night-soil, is somewhat volatile even at low temperatures and escapes in considerable quantities, if the air is warm, the excreta will suffer *a loss of nitrogen* [1] especially while they are stored without dilution for a later application, because then, after decomposition the concentration is very high. The volatilization of the ammoniacal compound will, moreover, be still more favoured by the free access of air, as the tubs are usually not covered by the farmers, but merely kept under a roof to protect the dung from the sun and rain. According to European researches [2] the loss of nitrogen from putrefying excreta may attain enormous proportions; thus Fr. Erismann reports having found, that from a night-soil pit containing 24 cubic meters of dung, there escaped into the air 2.04 kilograms of ammonia in 24 hours, and H. von Somaruga and Varrentrapp estimate the loss to amount to $^1/_3$–$^1/_2$ of the total nitrogen, when the excreta are stored in the usual manner. As in this country the night soil is not kept for so long a time in the closets or fermenting tubs as in Europe, and as the arrangements for collecting and storing it are generally good, capacious glazed earthénware vessels, oil tanks, or saké tubs serving mostly as receivers, it is not very likely that the loss will be so great as in Europe, where very little care is bestowed on this manure. Nothing being, however, known of the degree to which this process takes place under the ordinary treatment of the excreta in Japan, we deemed it necessary to investigate the subject.

---

1) According to investigations which I made in conjunction with Mr. *T. Yoshii* (Zeitschrift für physiologische Chemie 1887, vol. 12, p. 95) a liberation of elementary nitrogen cannot take place in putrefying materials so dilute as are the human excreta.

2) J. König, Stickstoffvorrath, 1887, p. 110.

The question, how much ammonia escapes while the dung is fermenting and being stored might be decided by estimations of the nitrogen in several subsequent periods of a given weight of excreta, if at the same time the quantity of water lost by evaporation is determined by weighing or measuring the whole of the dung. In experimenting, however, on large volumes, as is unavoidable in this case, the operations of ascertaining the weight or volume are not very convenient; for which reason it appeared to me to be the most accurate and easy way, to estimate at several periods besides the nitrogen, also the chlorine, an ingredient occurring in a large proportion in the dung, especially as this is not liable to evaporation or precipitation while the whole mass is stored, and as it admits of a very reliable analytical method for its quantitative determination. If water evaporates, the percentage of chlorine must show a proportional increase, from which the quantity of water lost can be calculated, and if ammonia escapes, the original proportion between chlorine and nitrogen must alter, e. g., for every part of chlorine less nitrogen will be found than in the original fresh dung. We proceeded in the following way:

A glazed earthenware vessel, 3 feet in diameter and 4 feet in depth, rather conically shaped toward the bottom was imbedded in the earth up to about an inch from the mouth, and filled with about 700 liters of excreta that had been collected during the preceding 8-10 days from the houses of officials. This was poured into the above vessel after having been well mixed and strained through a sieve with meshes wide enough to retain foreign substances, but not dung. The vessel was covered with a straw roof resting on a hurdle-work of bamboo, which did not interfere with good

ventilation. Samples were then taken from time to time after a vigorous stirring of the fermenting dung; about 3 liters were transferred from the centre of the vessel into a capacious bottle in which the mass was strongly shaken until no lumps, however small, could any longer be perceived. The specimens for the analyses were then at once measured. For the nitrogen determination 50 c.c. of the dung were oxydized according to the method of Kjeldahl and diluted with water, from which solution $^1/_{10}$ was taken, after cooling, for the distillation of the ammonia. The chlorine was estimated in the gravimetric way according to Neubauer's method. The entire analytical work was performed in these researches by Mr. *Y. Mori*.

To ascertain whether the temperature has any influence on the loss of ammonia, we carried out 3 such trials, in winter, in spring, and in the hot season (July and August). There was found in grams per 1000 c.c. of the dung:—

First Trial.

	Original night-soil Febr. 20th.	Fermented night-soil.	
		February 27th, after 1 week.	March 11th, after 3 weeks.
Nitrogen	7.90	7.76	7.55
Chlorine	6.05	6.11	6.16
Loss from 1000 c.c. of original dung:			
Water	—	8.2	16.2
Nitrogen	—	0.204	0.472
Loss of nitrogen, per cent of the nitrogen applied	—	2.58	5.98

Second Trial.

	Original Night-soil, April 24th.	Fermented night-soil.				
		May 8th, after 2 weeks.	May 15th, after 3 weeks.	May 29th, after 5 weeks.	June 12th, after 7 weeks.	July 9th, after 11 weeks.
Nitrogen	7.97	7.62	7.56	7.28	7.05	6.73
Chlorine	5.86	5.88	5.94	5.99	6.02	6.05
Loss from 1000 c.c. of original dung:						
Water	—	3.4	13.2	21.7	26.5	31.4
Nitrogen	—	0.369	0.504	0.842	1.109	1.607
Loss of nitrogen, per cent of the nitrogen applied	—	4.63	6.32	10.57	13.92	20.17

Third Trial.

	Original night-soil, July 6th.	Fermented night-soil.	
		July 23rd, after 2 weeks.	August 13th, after 5 weeks.
Nitrogen	7.22	6.95	6.46
Chlorine	5.62	5.70	5.76
Loss from 1000 c.c. of original dung:			
Water	—	14.4	24.3
Nitrogen	—	0.367	0.916
Loss of nitrogen, per cent of the nitrogen applied	—	5.09	12.70

These results show plainly that the quantity of ammonia which evaporates at and after the putrefaction and fermentation of human excreta, while storing them, is not

great. After three weeks there had been lost from 100 parts of the total nitrogen applied, in winter only 5.98, in spring 6.32, and in summer (according to a calculation) about 7.5 parts. As under ordinary practical conditions the time of fermentation is still shorter and the concentration much smaller, the losses should not amount to more than 3-4 %, a quantity so small, that no admixtures for the purpose of preventing the escape of ammonia, such as gypsum, humus, etc., are necessary. In fact, Japanese farmers do not resort at all to substances of that kind, but they may be recommended to apply them in all cases in which a long storing is intended, especially in summer, when as our results indicate, the high temperature of the air favours the evaporation of the ammonia. Besides this, a lid well fitted on the fermenting tubs to prevent the circulation of the air, may also render good service.

It appears, moreover, from our researches that during the cold or moderately warm part of the year the losses of nitrogen gradually diminish as the storing is continued. There escaped by evaporation per week from 100 parts of the nitrogen of the original night-soil:

First Trial (Winter).

Within the 1st. week	2.58	parts,
„ „ 2nd. & 3rd. weeks	1.70	„

Second Trial (Spring).

Within the 1st. & 2nd. weeks	2.32	parts,
„ „ 3rd. week	1.69	„
„ „ 4th. & 5th. weeks	2.13	„
„ „ 6th. & 7th. „	1.68	„
„ „ 7th. to 11th. „	1.55	„

Fermentation and putrefaction are usually associated with the production of heat, and as these processes are most vigorous in the first stages of storage, when fermentable

substances are still abundant, the warmth of the night-soil, attains also its maximum not long after the act of excretion. When afterwards the activity of the fungi diminishes and finally ceases the temperature of the fermenting mass will also fall and finally sink to that of the surrounding air or soil. As the evaporation of ammonia is, of course, greatly favoured by heat, it will take place at the time of strong fermentation to a greater extent than later on, but it will never be entirely checked unless there should be no more carbonate of ammonia in the dung. In the hot season the mass will cool very slowly, and not so much as in the other seasons of the year. Hence then the rate of evaporation cannot *much decrease during the time of storage.*

This is also proved by our researches ; we found in trial No. III. (in July and August) the rate of nitrogen lost from 100 parts of nitrogen originally stored to be as follows :

Within the 1st. & 2nd. weeks	2.55 parts,
,, ,, 3rd.—5th. ,, ...	2.54 ,,

The evaporation of water which continually takes place, while the night-soil is stored, is not considerable, amounting to only 31.4 $^0/_{00}$ of the total excreta after eleven weeks in the spring, and to 24.3 $^0/_{00}$ after five weeks in the hottest time of the year. During the winter it seemed to be accomplished even at a slightly higher rate than in summer, probably on account of differences in the relative moisture of the air, which is indeed during the Japanese winter (67 $^0/_0$) not so great as it is in the summer (82 $^0/_0$). The presence of a large proportion of soluble organic and inorganic compounds in the excreta is the principal reason for the very slight extent to which the water is lost. A relation between the evaporation of ammonium carbonate and that of water cannot, of course, be expected, as the tension of their vapours is entirely different.

As already stated, the Japanese farmers are accustomed

to apply the night-soil only after it has been well decomposed, the reason given being that the plants manured with fresh dung, are liable to wilting. I have tried, with the cooperation of Mr. *Y. Kozai* and others, to find an explanation for this *difference between the action of fresh and well rotted excreta,* and may give here a brief sketch of the results[1] obtained.

Neither the fresh nor the decomposed excreta contain, so far as our knowledge goes, direct poisons to the plants, and also the acid reaction of the former cannot disturb the vegetation, because all ordinary soils possess to a high degree the power of neutralizing the acid phosphates to which the reaction of the urine is due, and besides this, plants even prefer acidulent nutritive fluids to alkaline ones. It furthermore seemed, a priori, most probable that the injurious action of the fresh excreta might be caused by a soluble ingredient, since the wilting appears as a matter of course only in young crops upon top-dressing them with the dung and since the roots cannot be reached in this case by the undissolved portions of the manure. Now the fresh excreta are distinguished from the decomposed particularly by their content in urea, a soluble compound of weak affinities which is not likely to enter chemical combinations in soils and thus to be retained in the superficial layers in the so called absorbed state, as is the ammonia of decomposed dung. However, as it was not yet known whether the urea is capable of undergoing absorption or not, we undertook some researches on this subject. Of the air dry surface soil of the paddy field of Komaba 50 grams digested for 48 hours, with 100 c. c. of solutions of urea containing in the said volume 4.835 resp. 2.418 grams of urea did not take up any amount of the latter substance, while, when

---

1) A full record of these researches has already been published in "Landwirthschaftliche Jahrbücher," vol. 15, 1886, p. 712.

treated with a solution of ammonium chloride of a content of nitrogen equivalent to the last mentioned quantity of urea, it absorbed a considerable proportion (0.183 grams.) of nitrogen. By another experiment in which a solution of 8.1654 % urea was filtered through a burette containing the same kind of soil, the same result was arrived at. *Soils have consequently not the power of absorbing urea.*

This fact suffices to explain the injurious effect of fr urine or excreta in the following way : *As the urea remai in a dissolved state after top-dressing the crops, the concentration of the fluids in the soil may become so strong that the absorption of water by the roots is interfered with, whence the green organs are caused to wilt.* Human urine contains, according to the average of many determinations, about 2 % of urea besides 1.5 % common salt and sulphates, and if diluted even with a threefold volume of water, it remains still concentrated enough to hinder the plants from absorbing sufficient water, since in numerous experiments on the growth of plants in nutritive solutions, concentrations of 0.5 % caused failures. On the other hand, well decomposed urine reduces the diffusion of water into the roots but in exceptional cases, viz. if the absorptive power of the soil for basic nutrients is very low and if it is poor in moisture or liable to dry up. In such soils, however, every easily soluble manure may have or acquire that influence.

The application of fresh excreta to crops is also objectionable from another point of view. Since the urea which constitutes the principal nitrogenous and effective ingredient of the urine, remains dissolved in the fluids of the soil, it is *liable to be washed down by rain* and thus to be carried beyond the reach of the roots. It is true, the micro-organisms of the excreta and those contained in the soil will gradually convert the whole of the urea into carbonate of ammonia, but this process takes some time,

and before it is completed, rain may set in and carry the portion yet unconverted into the subsoil to a depth where the respective micro-organisms no more exist. The depth of the soil to which the conversion can be effected not being known was likewise subjected to an investigation, in which I was assisted by Mr. *H. Yoshida.* We took in calm weather samples of 50–60 grms. from different layers of the soil of the college farm, filled them at once into flasks previously sterilized by heat and closed with sterilized rubber plugs. After transporting them to the laboratory, we mixed them with 200 c.c. of a solution of urea sterilized by boiling, at the same time closing the flasks without delay. We are far from pretending that we succeeded by these measures in entirely preventing micro-organisms other than those of the soil from entering the vessels, but we believe, on account of our results, that we at least avoided essential disturbances, which would surely have taken place, if any considerable infection with atmospheric germs had occurred. We then drew small samples from the flasks from time to time, and determined the quantity of ammonia formed. The surface soil of a depth from 0–5 centimeters had the strongest effect; between the 9th and 16th day of the digestion, the conversion of the urea was completed; the sample from a depth of 25–30 centimeters the ammonification was likewise soon perceptible, but it continued very slowly and was not complete after 2 months; earth from deeper layers than the preceding ones still contained, after 37 days, all the urea applied. In accordance with these results it may be safely assumed, that the capacity of soils imparted to them by micro-organisms for converting urea into ammonium carbonate gradually diminishes as the depth increases, and that it is practically nil in layers deeper than about 50 centimeters. In applying fresh urine farmers would run the risk not only of damaging the crops but also of losing a more or less considerable part of the

nitrogen of the manure. They are consequently fully justified in subjecting human excreta to thorough decomposition before using them.

Night-soil that has been effectively disinfected, behaves with regard to its principal nitrogenous ingredient, just like undecomposed excreta; the addition of the disinfectant, having the effect of destroying all micro-organisms or at least of preventing them from growing and increasing, thus entirely suspends the conversion of the urea into ammonium carbonate and in other respects also deteriorates the dung. From the agricultural standpoint the following objections may be raised on the whole *against disinfected excreta:*

1.) They do not undergo decomposition and their application may cause, on account of their large content of urea, injuries to the crops and loss of nitrogen, as above explained.
2.) They contain less of fertilizing ingredients, as the addition of the disinfectant involves a more or less considerable dilution; hence their transportation is connected with greater expense.
3.) The disinfectant may be poisonous to plants, and the excreta may consequently be either entirely unfit for manuring purposes or, at least, be applicable only for special crops and under special conditions, or they may require a special treatment to render the disinfectant harmless.

With regard to the third point, which alone has to be decided by direct observation, we carried out some experiments, of which we here briefly state the results:

Carbolic acid[1] when mixed with water in which seeds were steeped for germination, retarded the latter in the case

1) A detailed description of researches on this disinfectant was published in "Landwirth schaftliche Versuchsstationen," vol. 30, 1883, p. 52.

of wheat and soy beans even when the solution contained only 0.05 %, and suspended the germinative power of some of the former seeds at 0.1 %, of the latter at 0.05 %. In field experiments with barley, which was sown in the Japanese fashion upon the night-soil, after spreading and allowing the latter to be sucked up by the soil, a content of the diluted excreta of 0.25 % of carbolic acid, essentially retarded the germination, while 1 % of the disinfectant killed the seeds entirely. If rain is allowed to act on the dung before sowing, the carbolic acid is washed away and does no more harm even after a strong admixture of the drug, but as already mentioned, the valuable urea is likewise carried away. When given as a top-manure, in which case the excreta are also usually diluted, a young wheat crop of a height of 10 centimeters was entirely destroyed at an admixture of 2 % of carbolic acid, while at later periods of growth even 3 % solutions were still harmless, provided, of course, that the night-soil was not poured directly upon the plants, but into a furrow along the lines of the drilled crop. Hence we recommend the application of the excreta mixed with carbolic acid only as a top-manure in a well diluted state and for not too young crops.

Ferrous sulphate[1], which is sometimes mixed with the night-soil has only weak disinfective properties, and chiefly serves as a deodorizer. Within the ordinary limits of the quantities applied, it does not interfere with the growth of crops, as even the high proportion of 30 grms. of the crystallized salt per liter of diluted night-soil did not exert any injurious influence on the germination and further development of barley. In agricultural practice too, no fatal effects of ferrous sulphate when mixed with excreta seem to have been observed.

---

1) A treatise on the influences of ferrous compounds on vegetation by the author will be found in "Landw. Versuchsst." vol. 32, 1886, p. 365.

We may now turn to the discussion of the *fertilizing properties of human excreta.* Compared with other manures the night-soil is, as the analyses given on p. 4 and 5 show, very poor in organic substance in relation to its contents in nitrogen. In all those cases in which the porosity of the soil is deficient and an increase of the humus is needed, excreta cannot consequently constitute the only manure for many years, but must be supplemented with vegetable materials, such as straw, chaff, leaves, grasses, seaweeds, etc., with which they are best made into compost. Furthermore, owing to their richness in easily soluble ammoniacal salts their effect on sandy not well decomposed soils, which are so frequent in Japan, will likewise not attain the degree to be expected from their richness in vegetable nutrients, because these soils have not the power of protecting the fertilizing ingredients from being washed down deep into the subsoil by the rains so frequent in this country. For these soils composted vegetable matters are preferable unless the farmer possesses the skill and time to nurse up the crops so to say, by frequent applications of well diluted dung. Only where the farms are small, and the working power is superfluous, this practice promises success, though not with the same certainty as when an appropriate quantity of slowly decaying vegetable manure is applied, which yields a slow but sufficient flow of nitrogen throughout the period of growth, and does no harm in times of drought.

In order to ascertain how far the relative proportion of the nutrients of the excreta coincides with the needs of the crops, we may first calculate the maximum produce that can be obtained from the nitrogen of 1000 liters of night-soil, provided that all other nutrients exist in the field in suitable and sufficient proportions and that the other conditions for a normal growth, such as light, heat, and moisture, are favourable. As under suitable circum-

stances about 60 % of the nitrogen applied passes over into the crops and as 1000 liters of excreta contain 5.5 kilograms of this nutrient, there may be taken up by the crop **3.3** kilograms of nitrogen. We may illustrate such calculations with the barley crop. This produces generally $1^1/_2$ parts of straw to every 1 part of grain, and the former contains, on an average of many analyses, 0.6 % of nitrogen, the latter 1.7 %. Now, if 3.3 kilograms of nitrogen enter the raw crop, the grain must contain......2.16 kilograms.

the straw......1.14 „

total...3.30 „

These quantities of nitrogen correspond to

127 kilograms of grain and

190 „ „ straw.

We have now to examine, whether the excreta contain phosphoric acid enough for this produce. Under ordinary conditions, such as are met with in practice, crops take up only about 15 % of the phosphoric acid applied in the best forms of manures. Applying this measure also to the phosphates of the excreta, but remembering always that it involves the maximum effect, we find that of the 1.3 kilograms of phosphoric acid contained in 1000 liters of night-soil only **0.20** kilograms can be actually taken up by crops. On an average of numerous analyses, barley grains contain 0.56 %, the straw 0.19 %, of that nutrient, hence the above yield obtainable from the nitrogen alone will then require the following quantities of phosphoric acid:—

0.71 kilograms for the grain and

0.36 „ „ „ straw.

1.07 „ „ „ total crop.

As only 15 % of the phosphoric acid applied enters the crop, there ought to be contained in 1000 liters of excreta for the cultivation of barley 7.13 kilograms, while the actual quantity amounts only to 1.3 kilograms. Hence 5.83 kilograms of phosphoric acid in an easily soluble form must

be added to the field, otherwise the nitrogen of the excreta cannot contribute effectually to the growth of the crop; indeed it may cause a scanty formation of grain and lodging.

The following table gives the results of similar calculations for other crops.

	Produce corresponding to the nitrogen contained in 1000 liters of night-soil.		Phosphoric acid	
	Grains. Kilogrms.	Straw. Kilogrms.	Needed for this produce. Kilogrms.	Required for supplementing the excreta. Kilogrms.
Wheat	106	150	7.8	6.5
Barley	127	190	7.1	5.8
Oats	106	175	8.0	6.7
Maize	127	175	9.3	8.0
Buckwheat	127	195	12.7	11.4
Rice	124	190	5.3	4.0
Rape	64	180	10.0	8.7
	tubers	foliage		
Potatoes	800	90	9.5	8.2
	roots	foliage		
Carrots	1120	170	9.3	8.0

It will easily be seen from these figures that human excreta do not constitute a complete fertilizer, since for none of the above common crops do they contain phosphoric acid enough to secure a good growth, and a similar calculation would prove, that they are also too poor in potash to supply by themselves the demand of crops. The amounts given in the table of phosphoric acid needed to supplement the night-soil, represent phosphoric acid freely soluble in water and should be regarded as the minimum quantities to be added, because on the one side a considerable part of the phosphates of the excreta exists in an insoluble state and cannot come into contact with the roots when the dung is applied as top-manure, the insoluble portions being then retained in the superficial layers of the soil, whither the roots do not grow; and on the other side

we assumed in our calculation a high rate (15 %) of action of the phosphates, both as regards those contained in the night-soil and those given as additional manure. In the present exhausted condition of Japanese soils it will be most advisable not to apply too small proportions of phosphates (fermented bones, superphosphates), but rather to approach as near as possible to the standards given by P. Wagner[1] who recommends that a general manure should contain for every 100 parts of nitrogen

for the cultivation of cereals...200 p. of phosphoric acid and
200 ,, ,, potash,
,, ,, ,, ,, beets[2] ...200 ,, ,, phosphoric acid,
,, ,, ,, ,, potatoes[2] 160 ,, ,, ,, ,,

Compared with the above, there exist in the fermented night-soil for every 100 p. of nitrogen only about.
25 ,, ,, phosphoric acid and
50 ,, ,, potash

To secure a maximum produce of the manures applied, the plants must be enabled to take up for every part of nitrogen a corresponding quantity of phosphoric acid, and if liberally supplied with an easily assimilable form of nitrogenous food, they exhibit at the same time a great demand for phosphoric acid, without which nutrient the nitrogen taken up remains useless, or interferes with the production of grain. The ammoniacal compounds of the excreta are, indeed, very speedily consumed by the plants, especially in this country, where the warm climate greatly favours the conversion of the ammonia into nitric acid, the most suitable and most soluble form of nitrogenous food. A liberal

---

1) Important practical questions on the subject of manures, 1885, p. 63–67.

2) These crops have a remarkable capacity for appropriating the potash of the soil, and seem, as a rule, not to require a direct supply with that nutrient, but derive more benefit from a surplus of potash manure given to the preceding crop.

supply of night-soil, like all effective nitrogenous fertilizers, has a powerful influence upon the tillering of the young plants and if the increased number of stems then do not find sufficient nitrogenous and phosphatic food, their functions are paralysed and the formation of grain cannot be accomplished to a normal extent. Hence a good supply of phosphoric acid to the plants should be regarded as particularly essential in all those cases where human excreta, and especially urine alone, constitute the exclusive or predominating fertilizer.

With reference to the deficiency of the night-soil in potash we may remember that many soils contain a large stock of this nutrient, and that also the vegetables and ashes which are frequently applied for the preparation of compost are rich in it. Moreover, all root and tuber producing crops have a special power of appropriating the potash compounds of the soil to an extent refused to cereal and leguminous plants; nay more, they rarely profit from a direct supply of potash, but prefer to feed on potash applied to preceding crops. In any case, attention should also be paid to this deficiency of the excreta, and trials made with the various cultivated soils to test whether the application of potash is profitable.

Under the present condition of the farming classes and of the trade in concentrated fertilizers in this country, it should be particularly kept in mind, that by composting the night-soil with vegetable materials the ratio of the nutrients is doubtless much improved, and still more so by the application of ashes from wood and various kinds of straw, both which additions are widely resorted to by Japanese farmers. The best way, unfortunately made impracticable at present by many circumstances, of supplementing the ratio of nutrients in the excreta, is undoubtedly the liberal application of rapidly acting phosphates besides the additional manures (compost, ashes) already mentioned. For *cereals*,

roots, and *beets*, such manures should be put into the furrows and well mixed with earth before sowing, while the chief part of the night-soil should be applied, as is actually done at present, in a well diluted state and in several doses, due regard being paid to the tillering of the plants, which ought not to be carried beyond a moderate point, dependent on the quantity of phosphoric acid in the first manure. For *leguminous crops*, however, which have the capacity of appropriating the atmospheric nitrogen in later stages of growth, only a slight supply of night-soil is recommendable before sowing; they require a liberal application of phosphoric and potassic manures and lime, which may be most suitably given in the form of wood and straw ashes; any further supply of excreta by way of top-dressing will not have a great effect, as it can merely act by the small content of phosphoric acid and potash.

On the Valuation of Japanese Fertilizers.

By

Dr. O. Kellner.

The concentrated fertilizers, chilisaltpeter, sulphate of ammonia, Peruvian guano, superphosphates, Thomas phosphate, potash salts, etc., are still almost entirely unknown to Japanese farmers. The first attempt to manufacture superphosphate in the country itself has only just been made, and the products placed on the market are still too expensive and of inferior quality. Instead of introducing such kinds of these fertilizers as would convince the farmers of their great efficacy and establish a demand for artificial manures, the importation of raw phosphates and the manufacture of superphosphates was at once commenced, and products were thrown on the market, which have a very doubtful value, and are, of course, too expensive, since the transport of a rock of 24 % of total phosphoric acid from Europe or America to Japan costs about twice as much as the import of a concentrated superphosphate of 40 – 50 % of soluble phosphoric acid. If artificial manures of low fertilizing power continue to be recommended to the farmers, just the opposite of what is aimed at will be arrived at; people will refuse to purchase a second time manures entirely new to them, unless they really find them profitable when trying them for the first time.

At present, the only trade in fertilizers, worth speaking of, is that in ***dried fish, various kinds of brans, oilcakes, wood***

and straw ash, lime, and *night-soil,* so far as the latter is transported by associations of professional scavengers from cities into the country, where the manure is sold, or so far as it is directly purchased or exchanged against vegetables, wood, etc. by the farmer, who carts it home himself. The prices paid to the citizens for the night-soil are, of course, subject to great fluctuations according to the size of the city, the season of the year, the method of transport e. g., whetherby boat, by cart, etc. Hence it is quite impossible to calculate a reliable absolute value for a unit of nitrogen, phosphoric acid, or potash, contained therein. Of the other commercial manures above mentioned, dried fish, bran, and oilcakes, being distributed uniformly enough over the districts where agriculture is carried on intensively, afford a better basis for determining the money value of the principal vegetable nutrients in Japan.

As to the *relative value* of these nutrients e. g., the proportion between the prices paid for them, it is, however, at present quite impossible to arrive at any accurate figures. We must be satisfied with an approximate adjustment based on the valuations of them in other countries, and need not fear to commit any great error, since even in countries so different as Germany and the United States, the ratio between the values of the nutrients is almost invariably the same. There the extensive trade in concentrated fertilizers has guided us to the establishment of certain scales which admit of an easy judgment as to the actual price of artificial fertilizers. In Germany according to E. von Wolff. the following prices in *marks* are paid for *one kilogram* of each nutrient:

I. *Nitrogen,* in the form of ammoniacal salts and nitrates, or in easily soluble or decomposable organic substances, such as dried and powdered blood, flesh meal, Peruvian guano 1.40-1.60

I. *Nitrogen,*	in the finest steamed bone dust, fish manure, oil-cakes, poudrette, and in all superior kinds of artificial guano	1.20-1.40
,,	in granular or finely splintered sorts of bone dust, horn meal, and wool dust	1.00-1.20
,,	in coarse fragments of bones and horn, woollen rags, human excreta, stable dung, etc.	0.80-1.00
II. *Phosphoric acid,*	soluble in water, such as in superphosphates	0.70
,,	in Peruvian guano and precipitated phosphates	0.60
,,	in the finest steamed bone dust, fish meal, poudrette, and as "reverted" phosphoric acid	0.50
,,	in the raw Baker guano and in most other natural guanos poor in nitrogen, also in wood ashes	0.44
,,	in granular or finely splintered bone dust, finely powdered animal charcoal, and in bone ash	0.40
,,	in raw fragments of bones, human excreta, farm yard manure, powdered phosphorites, Thomas phosphate powder, coprolites, and other ferruginous phosphates, raw refuse from various materials of manufacturing processes	0.30
III. *Potash,*	loco Stassfurt, in raw minerals ...	0.12-0.16
,,	,, ,, in purified salts ...	0.24-0.36

In addition to this we may quote the trade values agreed upon by the experiment stations of Connecticut, New Jersey, and Massachusetts, for the year 1887 :

		Cents per lb.
I. *Nitrogen,*	in ammonia salts, dried and ground fish, azotin, ammonite, dry ground meat, castor pomace	17.5
,,	in dried and fine ground blood	16.5
,,	,, nitrates, and fine ground bone and tankage	16
,,	in fine-medium bone and tankage	14
,,	,, medium bone and tankage	12
,,	,, coarse-medium bone and tankage ...	10
,,	,, coarse bone and tankage, horn shavings, hair and fish scraps	8
II. *Phosphoric acid,*	soluble in water	8
,, ,,	soluble in ammium citrate... ...	7.5
,, ,,	in dry ground fish, and in fine bone and tankage...	7
,, ,,	in fine-medium bone and tankage...	6
,, ,,	in medium bone and tankage ...	5
,, ,,	in coarse-medium bone and tankage...	4
,, ,,	in coarse bone and tankage ...	3
,, ,,	in fine ground rock phosphate	2
III. *Potash,*	as high grade sulphate free from chlorides	5.5
,,	as kainite and muriate	4.25

These tables will show that the proportion of the retail cost of the phosphoric acid and nitrogen is nearly the same in the two countries. Take, for example, the dry ground fish (fish meal) ; in this manure the proportion is in Germany 0.50 : 1.20—1.40 or 1 : 2.5—2.8 and in North-America 7 : 17.5 or 1 : 2.5. In coarse fragments of bones it is 1 : 2.7—3.3 in the former, and 1 : 2.7 in the latter states. Hence we can safely assume that also in Japan a similar proportion will not be far from the truth, but as phosphatic min-

erals, or guano, have not yet been discovered within easy reach of this country, the ratio will be a little more narrow. Hence we may take it to be 1 : 2.5 in all ordinary vegetable and animal fertilizers, such as brans, oilcakes, refuse materials from the manufacture of *saké*, alcohol, *shoyu* and *tofu*, and in the coarse fish manure.—The price of the potash can be approximately determined on account of the trade value of the straw ashes, of which 100 *kuwamme* cost in Tokyo with slight variations about 3 Yen, and which contain, on an average of several analyses, 8.13 % of potash and 1.06 % of phosphoric acid. As according to our subsequent researches 1 *kuwamme* of the latter ingredient has the average value of 0.608 Yen, a simple calculation shows that the same unit of potash is worth 0.290 Yen.

With the help of the above ratio for the relative value of phosphoric acid and the price of potash it will be possible to calculate how much is generally paid in Tokyo for nitrogen and phosphoric acid, provided that we know the prices of commercial fertilizers with sufficient accuracy. Information on this latter subject has been communicated to me by Mr. *K. Hirata*, who compiled from a magazine (Tokyo-Keizai-Zasshi) the prices paid in Tokyo during the last 7 years (1882-87) for the following materials :

No.	General name.		Special name in the Tokyo market.
	English.	Japanese.	
1	Dried herrings.	Shime kasu.	Uchi umi kasu.
2	„	„	Sendai „
3	„	„	Isomura „
4	„	„	Hachinobe „
5	„	„	Tarumai „
6	„	„	Koshinaga „
7	Dried sardines.	„	Nishin „
8	„	„	Atsugishi konishin „
9	Dried herrings.	Hoshika.	Honba hoshika.
10	Rape cake.	Tane kasu.	Tane kasu.
11	Rice bran.	Nuka.	Zomei.
12	„ „	„	Hachiken.

The prices given by the magazine for rape cake and rice bran did not show great fluctuations during the year, and those for fish manure were also pretty constant from March to August, while for the rest of the year (September to February) the fluctuations were very considerable, owing to the periodical demand and irregular supply of the market. Hence, Mr. *Hirata* calculated these prices separately for the two seasons of the year, and drew up the following tables, in which the averages from March to August will be found under No. I., and those for the other months under No. II.

For one Yen there were sold the following quantities in *kuwamme* (1 kuwamme = 3.75652 kilograms):

Year.	No. 1.			No. 2.			No. 3.		
	I.	II.	Average.	I.	II.	Average.	I.	II.	Average.
1882	4.1	4.9	4.5	4.2	4.6	4.4	4.2	4.6	4.4
1883	4.7	6.4	5.6	4.7	6.4	5.6	4.7	6.4	5.6
1884	5.5	6.7	6.1	5.7	6.6	6.2	5.8	7.6	6.7
1885	5.4	6.3	5.9	5.5	6.4	6.0	—	6.7	6.7
1886	5.3	5.2	5.3	5.5	5.1	5.4	—	—	—
1887	3.9	3.9	3.9	4.2	4.1	4.2	—	—	—

Year.	No. 4.			No. 5.			No. 6.			No. 7.		
	I.	II.	Average.	I.	II.	Average.	I.	II.	Average.	I.	II.	Average.
1882	4.6	5.4	5.0	4.6	5.0	4.8	—	—	—	4.8	5.2	5.0
1883	5.2	7.2	6.2	5.4	7.7	6.6	—	—	—	5.2	7.1	6.2
1884	6.1	7.3	6.7	6.1	—	6.1	6.7	7.7	7.2	6.3	7.5	6.9
1885	5.7	6.7	6.2	6.4	7.2	6.8	7.2	7.7	7.5	6.4	8.2	7.3
1886	6.1	5.9	6.0	6.0	5.8	5.9	6.7	6.6	6.7	7.8	6.6	7.2
1887	4.8	4.6	4.7	4.7	—	4.7	5.5	5.0	5.3	5.6	4.9	5.3

Year.	No. 8.			No. 9.			No. 10.	No. 11.	No. 12.
	I.	II.	Average.	I.	II.	Average,			
1882	—	—	—	5.0	5.6	5.3	6.4	7.68	8.88
1883	—	—	—	6.4	8.8	7.6	9.6	12.24	14.04
1884	—	—	—	7.8	11.0	9.4	12.0	13.56	14.76
1885	—	—	—	6.8	7.4	7.1	10.0	13.20	14.16
1886	—	—	—	—	—	—	10.0	12.72	14.40
1887	4.9	4.9	4.9	6.6	6.6	6.6	8.8	11.52	13.44

From these figures we see that the fluctuations of prices from one year to another affected all fertilizers alike, and that, consequently, the scarcity of one large group of them at once affects the price of all the others, it being very likely that the smaller or larger catch of fish is the standard for the retail cost of the other manures. In 1882 and 1887, high prices prevailed throughout, while 1884 and 1885 were remarkable for the cheapness of the manures. The table indicates furthermore that during the spring and in the beginning of summer, when the demand is high, the manures are more expensive than in winter, when the growth of the crops is at rest and less manure is needed.

In calculating the average prices of nitrogen and phosphoric acid it is requisite to know the contents of the above mentioned manures in these nutrients. Numerous analyses which have been made in our laboratory and to which also Mr. *Hirata* has contributed, have given the following results :

		In 100 parts of the air dry matter:		
		Nitrogen.	Phosphoric acid.	Potash.
1.	Uchi-umi kasu	11.71	4.80	0.7-0.8
2.	Sendai ,,	10.58	3.74	
3.	Isomura ,,	10.84	3.49	
4.	Hachinobe ,,	10.17	3.45	
5.	Tarumai. ,,	9.15	3.74	
6.	Koshinaga ,,	9.68	3.45	
7.	Nishin	9.10	4.46	
8.	Atsugishi konishin	8.44	3.26	
9.	Hoshika	8.51	4.47	
10.	Rape cake	4.57	2.02	1.28
11.	Rice bran	2.08	3.79	1.40
12.	,, ,,			

In 1882, the prices of *100 kuwamme* of each of these manures and the quantities of nitrogen and phosphoric acid contained therein were as follows:

	Price. Yen.	Nitrogen. Kuwamme.	Phosphoric acid. Kuwamme.
Fish manure.			
1. Uchi umi kasu	22.22	11.71	4.80
2. Sendai ,,	22.73	10.58	3.74
3. Isomura ,,	22.73	10.84	3.49
4. Hachinobe ,,	20.00	10.17	3.45
5. Tarumai ,,	20.83	9.15	3.74
7. Nishin	20.00	9.10	4.46
9. Hoshika	18.87	8.51	3.26
total	147.38	70.06	26.94

	Price. Yen.	Nitrogen. Kuwamme.	Phosphoric acid. Kuwamme.	Potash. Kuwamme.
Oil cake and brans.				
10. Rape cake	15 63	4.57	2.02	1.28
11 & 12. Rice bran	12.08	2.08	3.79	1.40
total	27.71	6.65	5.81	2.68

For 147.38 Yen we obtain in the form of fish manure 70.06 *kuwamme* of nitrogen and 26.94 *kuwamme* of phosphoric acid. Taking the value of the two nutrients to stand in the ratio 2.5 : 1, and omitting to include in our calculation the very small content of fish manure in potash (0.7-0.8 %), the price of 1 *kuwamme* is found to be

nitrogen ... ... 1.825 Yen.
phosphoric acid ... ... 0.730 ,,

In the oil cakes and brans the prices are higher, viz:

nitrogen ... ... 3.000 Yen.
phosphoric acid ... ... 1.200 ,,

Calculations made in the same way for the other years give the following prices per *kuwamme* of each nutrient:

Year.	Fish manure.		Oil cakes & brans.	
	Nitrogen.	Phosphoric acid.	Nitrogen.	Phosphoric acid.
1882	1.825	0.730	3.000	1.200
1883	1.427	0.571	1.923	0.769
1884	1.282	0.513	1.627	0.651
1885	1.310	0.524	1.833	0.733
1886	1.430	0.572	1.847	0.739
1887	1.840	0.736	2.070	0.828
Average.	1.523	0.608	2.050	0.820

Compared with fish manure, the oil cakes and brans have, according to these figures, a far higher price, obviously owing to their application for the feeding of live-stock and for various domestic purposes. They ought not to be used as manures at all, unless they could be got for about $^3/_4$ of their present price. The retail cost of fish manure, too, is not so low as might perhaps be expected having regard to the richness of the Japanese waters in fish ; the price for the nitrogen contained in them amounts in German money (1 Yen = 3.10 Mark) to 1.26 Mark per kilogram, and ac-

cording to American rates it equals about 14 cents per ℔. For these prices German farmers can get the same amount of nitrogen in the form of the finest sorts of steamed and very finely powdered bone dust and fish meal, almost free from oil and admitting of a very uniform distribution over the fields, while the Japanese fish manure consists of whole fish dried in the air, not freed from the oil at all, and necessitating before application careful preliminary treatment (pounding and fermenting). In America too, as in most European countries, the raw dried fish for manuring would sell at a considerably lower price than in the commercial emporium of Japan, in spite of the abundance of fish in the surrounding seas. For the Japanese farmer, however, who has hard work only during several short periods and enjoys much leisure during the rest of the year, it is a matter of indifference whether he gets commercial fertilizers in a very handy form, fit for immediate application, or whether he has to bestow some labour in the crushing and fermenting of the material; time is at present unfortunately but rarely money to him. What is possible in other countries less near a rich sea, ought, however, not to be impossible in Japan, so favourably situated; the farmers ought to be placed in a position to purchase raw fish manure at cheaper rates, than they can do at present.

Finally, much interest attaches to the determination of the value of *night-soil,* by the help of the above prices of the nutrients in fish manure and ashes. On the farm itself the nitrogen, phosphoric acid, and potash of the human excreta will have the same value as in the raw fish, since the preparatory treatment required by the two is similar; and whether a little more or less work is connected with their respective application, need not be seriously taken into account. Thus we find the following figures for 100 *kuwamme* of ordinary nightsoil:

0.55 kuw.	of nitrogen	=	0.838 Yen
0.13 ,,	,, phosphoric acid	=	0.079 ,,
0.27 ,,	,, potash	=	0.078 ,,
	total		0.985 Yen

In the neighbourhood of towns and cities farmers are accustomed to enter into agreements with householders and to purchase the excreta of a family for a sum dependent upon the number of its members. In Tokyo, where the prices thus paid will certainly be rather low on account of the great distances of the farms from the city, there is paid on the average 25-30 Sen per year for the excreta of an adult [1]. As the total quantity of dung deposited per year per head in the closet of each house may be estimated at about 100 *kuwamme,* which after it is carried to the farm, has a value of about 1 Yen, the farmer who carts the night-soil home himself within two half working days [2], realizes accordingly for the labour of transporting it about 70-75 Sen. According to the calculation of others, the annual quantity of excreta deposited per head of the population in their own houses amounts only to about 90 *kuwamme,* in which case he saves by the transport 67-73 Sen. This money, 67-75 Sen, represents an actual gain to the farmer, as he would be compelled to purchase the cheapest commercial fertilizer, i.e. fish manure, if he were to refuse to avail himself of the night-soil, and as he finds but rarely outside his farm an op-

1) In the agreements with families in Tokyo persons above 15 years are counted as adults, of children between 10-15 years two are accounted for as one adult, and children below 10 years are not at all taken into account. Unless such agreements exist, the night-soil is much more expensive, 12-13 Sen being paid for 1 *ka* (=82 kilograms=22 *kuwamme*) i.e. 55-60 Sen for 100 *kuwamme.* When bought from boats in a distance of 3-4 *ri* from the city the price of 1 *ka* is 13-15 Sen, i. e. 60-70 Sen for 100 *kuwamme.*

2) One man can usually draw by hand on his two-wheeled cart about 3 tubs of 15-16 kuwamme each to a distance of 2-4 *ri* (=8-16 kilometers) within half a working day.

portunity of profitably utilizing his spare working power. Under present conditions, the excreta of the population of towns and cities are by far the cheapest manure obtainable. Even if fish manure should still sink much in price, yet it will be economical for the farmer to resort to the night-soil of *cities*, if he is in a position to fetch it himself.

The preceding calculations and results apply, of course, only to Tokyo and similar Japanese cities with a large population, where the night-soil has at any rate to be removed. In towns and villages, where the quantity of excreta to be carried away is less, and the demand is greater, the cost of fish manure or night-soil may approach each other and perhaps be equal, while in those districts near the sea, where fish is plentiful, the fish manure may be even cheaper than human excreta.

Errata,

in Bulletin No. 2.

Page 31, 16th line from top, read in the column straw left total nitrogen *0.885,* instead of 18.85.

Page 38, in the heading of the table, column 4th, read *Fat* instead of *Fibre,* and column 5th read *Fibre,* instead of *Fat.*

Page 38, table, 1st line from bottom, digestion coefficients, average for fat read 88.31, instead of 89.31.

東京農林學校
學術報告
第四號

Imperial College
OF
AGRICULTURE & DENDROLOGY.

Komaba, Tokyo, Japan.

Bulletin No. 4.

Researches
on the Composition of several Japanese Fertilizers.

BY

Dr. O. Kellner,
Professor of Agricultural Chemistry.

明治廿二年三月
Tokyo, Japan, March, 1889.

Printed by 'Seishi Bunsha.'
No. 1, Kabutocho, Nihonbashiku, Tokyo.

Researches on the Composition of several Japanese Fertilizers.

BY

Dr. O. Kellner.

The nutrients without which green plants cannot attain any normal development and which are taken up from the soil through the roots are, besides water, the following: nitrogen, potash, lime, magnesia, sesquioxide or protoxide of iron, phosphoric acid, and sulphuric acid. Some of these, viz. magnesia, iron compounds, sulphuric acid, and mostly also lime are so copiously contained in all ordinary soils that even continual cropping without any artificial addition of them to the fields does not impair the fertility of the latter. *Nitrogen, phosphoric acid,* and *potash,* however, generally exist in soils in relatively small proportions insufficient to cover the need of cultivated plants, and are moreover withdrawn from the fields in the form of crops to such an extent as to diminish considerably the crop-feeding power of the soil. Hence arises the necessity of supplying the latter from time to time with these three nutrients in the form of manures, otherwise the fertile condition of the soil would not be maintained or improved.

All manures that contain one or more of the three nutrients just mentioned are called *direct* fertilizers, because they serve to directly feed the crops. Another group, called *indirect* fertilizers, to which belong lime, gipsum, common salt, etc., indirectly increase the produce, either by dissolving and distributing those nutrients which already exist in the soil, or by improving the physical conditions of the land, or by paralyzing certain injurious properties of

soils. It is only with some of the former group that the following paper is intended to deal.

The value of the direct fertilizers is dependent in the first place, of course, upon their content of nitrogen, phosphoric acid, and potash, but this is not their only value. The three vegetable nutrients must also exist in the manures in a form in which they can be taken up by the roots. Of the nitrogen, for example, in the form of leather, or of the phosphoric acid in the form of crushed rock phosphate the plants cannot much avail themselves, because in these materials the nutrients are so insoluble, and resistible to the decomposition in the soil, that their effect on the crops is hardly perceptible, or at least very slow. Thus, the solubility of the nutrients, resp. the ease with which the manures decompose in the soil, is a second important point in the determination of their value.

As already explained in No. 3 of the Bulletins of this College with reference to ordinary fertilizers of animal or vegetable origin, we shall not commit any serious error, if we assume in this country for the relative money value of nitrogen, phosphoric acid, and potash the proportion 5: 2: 1, e. g. if the value of a certain weight of nitrogen is 5, that of the same quantity of phosphoric acid is only 2, and of potash only 1. With the help of these figures it is easy to compare the costs and real value of several fertilizers and to find out which of them is cheapest. The following example, in which it is assumed that 100 *kuwamme* of tea seed cakes cost 3.50 YEN, the same weight of wax berry cakes (haji dama) 1.50 YEN, will illustrate this.

100 p. of wax berry cakes contain:

Nitrogen	1.16 ;	multiplied by the factor	5=5.80
Phosphoric acid.	0.42 ;	,, ,, ,, ,,	2=0.84
Potash	0.77 ;	,, ,, ,, ,,	1=0.77
		Sum of the manurial units	7.41

100 p. of tea seed cakes contain:

Nitrogen	2.13;	multiplied by the factor 5	=10.65
Phosphoric acid.	0.54;	,, ,, ,, ,, 2	= 1.08
Potash	1.99;	,, ,, ,, ,, 1	= 1.99
		Sum of the manurial units	13.72

According to this calculation 7.41 manurial units in the form of wax berry cakes cost 1.50 YEN; one unit costs consequently .... 20.24 SEN.

On the other side, 13.72 manurial units in the form of tea seed cakes cost 3.50 YEN; one unit costs consequently .... 25.51 SEN.

Thus we find that the actual price of the vegetable nutrients in the wax berry cakes is far lower, than in the tea seed cakes and that it would be more economical to buy the former, provided that their rapidity of decomposition in the soil is not much inferior to that of the tea seed cakes.

It must, however, be distinctly understood that by such calculations we can determine only the approximate money value of fertilizers, and by no means their effect on the crop, for the simple reason that different soils and plants have different needs. A farmer who intends to purchase fertilizers for cultivating wheat and has calculated in the above way that he can get wood ash at a much cheaper price than fish manure or other fertilizers, would, of course, be entirely wrong, if he were to manure the field only with wood ash, because in that case the wheat would not find sufficient nitrogen for its growth. It is the office of the farmer to apply the three nutrients in proper proportions, for which purpose one single kind of commercial manure will seldom be suited, but mixtures of several will mostly be necessary. The above method of calculating the money value will only help him to pick out from among the nitrogenous or phosphatic manures the cheapest kinds. Hence it should only be resorted to in comparing the value of fertilizers of a similar character.

The following pages contain the results of the chemical analyses of 63 different specimens of manures of the following description :

I.	Various kinds of fish manure	14	analyses.
II.	Kitchen refuse from fishes	9	,,
III.	Shells of sea turtle	1	,,
IV.	Various sea animals	3	,,
V.	Rice brans (mixture of 5 sorts)	1	,,
VI.	Oil cakes from the manufacture of vegetable wax	2	,,
VII.	Tea seed cakes	1	,,
VIII.	Saké cakes (average of 5 sorts).........	1	,,
IX.	Shoyu cakes (mixture of 5 specimens)	1	,,
X.	Tofu cakes	1	,,
XI.	Residues from the manufacture of indigo	3	,,
XII.	Green manure of Astragalus lotoides	1	,,
XIII.	Sea weeds	1	,,
XIV.	Wood and straw ashes (each mixtures of 5 specimens).........................	2	,,
XV.	Various kinds of straw and chaff ...	19	,,
XVI.	Dry leaves and grasses (straw) from forests	3	,,
	Total	63	,,

With regard to the methods applied in the present researches, the organic part of the manures was analyzed in the same way as described in Bulletin No. 2 (p. 5-6) for the feeding stuffs, and the ash according to E. von Wolff's "Anleitung zur Untersuchung landwirthschaftlicher Stoffe." The nitrogen was estimated by Kjeldahl's method, and the phosphoric acid in the fish manure and sea animalsw as determined after oxidation of the substances with strong nitric acid and fusion with carbonate and nitrate of soda by

precipitation with molybdic acid in the way elaborated by P. Wagner.

I. Fish Manure.

The only source of fertilizers other than produced by the soil, from which Japan has drawn during her long seclusion and still draws at present a constant supply to her fields, is the sea with its enormous wealth in animals and weeds. In the country itself nothing of guano, phosphorites, or potassic salts has yet been found, and judging from the meteorological and geological conditions there is also hardly any hope that fertilizing materials of that description will be discovered in future in quantities large enough to support the agriculture of the whole country. The sea, on the other hand, yields at present only a small fraction of what it might be made to contribute to the fertility of the land, directly, by a supply of manures, or indirectly, by a supply of human food. Fishing, although the occupation of many people, is carried on yet on a rather small scale and only in the proximity of the shores, and might be much extended by the application of modern methods.

Of the enormous number of fishes that are caught round the Japanese islands only two kinds make up the bulk of the fish manure produced, e, g. *herrings,* Clupea harengus (nishin) and *sardines,* Clupea melanosticta and gracilis (iwashi). According to the official statistics relating to the produce of fish manure, which comprise only these two kinds of fishes, the total average annual quantity manufactured during the three years 1882-1884 amounted to 1,443,637 *koku** of which $\frac{5}{9}$ were put out in the Hokkaido (Yezo), $\frac{1}{3}$ in Chiba prefecture, and only $\frac{1}{9}$ in all

* 1 *koku*=180.4 litres.

the rest of Japan. This quantity though considerable in itself, is not very large when compared with the demand of the entire cultivated land (about 4.5 million *cho*†) for fertilizers, or with the enormous extent of the shores of the Japanese islands. Of the other kinds of fishes which are occasionally made into manure, the following deserve to be mentioned: Scomber pneumatophorus japonicus (saba) Chatoesus punctatus (konoshiro), Trachurus trachurus (aji), Trichodon Stelleri (hata-hata), Ammodytis (konago), Hippoglossus vulgaris (okigarei) and various kinds of sharks.

According to the methods of preparation fishmanure is divided in Japan into *hoshika*, which is obtained by simply drying the fish in the air, and *shime kasu*, which is prepared by boiling, pressing, and drying, whereby a part of the fish oil is gained. A third kind, called *ara kasu* has recently been made from the heads, vertebræ, and tails of large fishes Thynnus Sibi (shibi) and Thynnus pelamys (katsuuwo) and consists of coarsely granulated fragments, while the two former sorts are made of whole fishes or large fragments of them.

The specimens of shime kasu and hoshika examined in our laboratory were the following:

No. 1. Shime kasu from sardines, produced in the inland sea (uchi umi), marked as 1st quality.

No. 2. Shime kasu from sardines, from the same place as No. 1, marked as 2nd quality.

No. 3. Shime kasu from sardines, made in the inland sea.

No. 4. Shime kasu from sardines, made in the province of Shimōsa as 1st quality.

No. 5. Shimekasu from sardines, made in the Miyagi prefecture.

† 1 *cho*=0.99174 hectare.

No. 6. Shime kasu from herrings, made in Hokkaido.
No. 7. Shime kasu from herrings, made in Hokkaido.
No. 8. Hoshika from sardines, made at Sankawa in Chiba prefecture.
No. 9. Hoshika from sardines from the same place (inferior quality).
No. 10. Hoshika from herrings, made in Hokkaido.

The composition of these 10 specimens was found to be as follows (per cent of the original substance):

A. Shime kasu.

	Sardines.					Herrings.	
	1.	2.	3.	4.	5.	6.	7.
Moisture	7.12	14.70	10.73	12.45	16.36	9.43	11.57
Organic matter	82.94	73.96	75.03	73.97	65.81	74.94	69.38
Ash	10.94	11.34	11.09	13.58	7.35	12.38	17.02
Sand			3.15		10.48	3.25	2.03
Nitrogen	*11.70*	*9.78*	*9.14*	*8.98*	*8.94*	*8.06*	*8.60*
Oil	7.78	9.71	3.89	10.86	9.40	12.18	16.60
Potash	*0.38*	*0.16*	*0.69*	*0.56*	*0.67*	*0.62*	*0.88*
Soda	0.71	0.33	0.97	0.88	1.42	0.46	2.11
Lime	2.87	4.61	3.98	2.78	2.12	5.27	5.99
Magnesia	0.53	0.37	0.42	0.27	0.22	0.67	0.84
Ferric oxide	0.27	0.02	0.30	0.41	0.30	0.34	0.24
Phosphoric acid	*4.73*	*4.85*	*3.99*	*3.33*	*2.86*	*5.96*	*5.02*
Sulphuric acid	0.10	0.02	0.30	0.07	0.14	——	0.17
Silica and sand	1.24	0.79	3.23	5.08	10.48	3.31	2.12
Chlorine	0.26	0.22	0.27	0.53	0.22	0.86	2.11

B. Hoshika.

	Sardines.		Herrings.
	8.	9.	10.
Moisture	8.27	5.73	17.91
Organic matter	69.35	64.85	61.45
Ash and sand	22.38	29.42	20.64
Nitrogen	*8.04*	*6.86*	*6.55*
Oil	14.50	18.16	17.65
Potash	*0.63*	*0.76*	*0.60*
Soda	0.87	0.91	1.47
Lime	3.20	4.01	2.56
Magnesia	0.34	0.76	0.74
Ferric oxide	0.94	1.53	1.99
Phosphoric acid	*3.45*	*3.88*	*2.27*
Sulphuric acid	0.11	0.29	0.34
Silica and sand	12.46	16.87	9.63
Chlorine	0 52	0.34	0.88

We learn from the preceding results that the Japanese fish manure constitutes an essentially nitrogenous fertilizer with a rather low content of phosphoric acid, and that the difference between *shime kasu* and *hoshika* is considerable, the former being richer in nitrogen but poorer in fat than the latter. Their average contents in those components upon which their value depends is, according to the above analyses, as follows:

	Shime kasu.		Hoshika.	
	Sardines.	Herrings.	Sardines.	Herrings.
Nitrogen............	9.7	8.3	7.5	6.6
Phosphoric acid...	4.0	5.6	3.7	2.3
Oil	8.3	14.4	16.3	17.7

Here the superiority of the shime kasu over the hoshika is clearly illustrated and, at the same time, it also becomes evident, that in each of the two kinds of fish manure preference must be given to that made from sardines, not only on account of their higher content in nitrogen, but also because of their less oily condition. It is true, the analysis of oily fish dried in the air cannot yield exact figures as to the oil, because a part of this ingredient is materially altered by oxydation, but this inaccuracy concerns more the hoshika than the shime kasu, since the latter manure is already freed from some oil before it is subjected to drying. Hence hoshika will be in a still more oily condition and consequently act still more slowly than is indicated by the percentage of oil as given in our results. A further drawback to the hoshika is the large quantity of sand which adheres to it, in consequence of its being prepared on the shore, which drawback might, of course, be easily avoided.

As the Japanese fish manure consists of whole fishes or large fragments and as it is usually rich in oil, it requires a careful preparatory treatment before application, otherwise its distribution over the field would be difficult, and the effect very slow. It must be well crushed and then subjected to a thorough fermentation in the compost bed. When industrial enterprise shall have grown out of its present state of childhood, attention will certainly be paid to the rational extraction of the valuable oil from the fishes and to the manufacture of a fine handy powder from the remainder.

Fish manure of a description other than shime kasu and hoshika is made in Japan only to a limited extent. Thus, by the manufacture of dried bonito (katsuo bushi) from Thynnus vulgaris (shibi maguro) and Thynnus pelamys (katsuo) two sorts of manure which are known as arakasu are gained from the offal, one being made from the heads, bones, fins, tails, and entrails of the two kinds of tunny, the other consisting of the dried scraps from the flesh of the fishes resulting when the latter is cut, pressed and dried after boiling.

Of each of these two kinds of manure two specimens, one bought in Tokyo and the other kindly collected for us at Ishinomaki, Miyagi prefecture by Mr. S. Tanaka and obtained from Thynnus vulgaris, were analyzed in our laboratory by Mr. *T. Yoshii*, now professor in the Imperial College at Sapporo. Both specimens represented a coarsely granulated mass mixed with larger fragments. Their composition, per cent of the original substance, was found to be as follows:—

	No. 1. Heads, bones, fins, etc.		No. 2. Scraps of meat.	
	a.	b.	a.	b.
Moisture	7.23	9.47	8.23	12.63
Ash	—	28.70	—	6.16
Fat and oil	11.33	14.56	18.01	15.22
Nitrogen	*8.16*	*5.34*	*13.01*	*10.50*
Phosphoric acid	*4.25*	*7.42*	*0.94*	*2.38*
Lime	5.14	—	0.65	—

The composition of these fertilizers is accordingly somewhat variable and dependent upon the content in bony matter. The scraps are extremely rich in nitrogen, and rank among the most valuable sorts of commercial manures.

II. Kitchen Refuse from Fish.

As fish form to a large extent the food of the Japanese people, the refuse left uneaten consisting of the heads vertebræ, tails, and some adhering flesh, if collected and' properly prepared, might become an important article in internal trade and would represent a manure closely related to the so called "fishguano" from Norway. In order to call attention to the agricultural value of these materials, Mr. *I. Honda* has analyzed specimens of refuse left from the following 9 kinds of marine fishes:

No.	Japanese name.	Zoological name.	Average length. Meters.
1.	Inada	Seriola aureovittata....................	0.25—0.4
2.	Aji	Caranx trachurus.........................	0.12—0.2
3.	Hirame	Pseudorhombus olivaceus	0.15
4.	Sawara.........	Cybium niponicum	0.3 —0.5
5.	Maguro	Thynnus thunnica	0.8 —1.3
6.	Karei	Pleuronectus variegatus	0.3
7.	Kochi	Platycephalus guttatus	0.3 —0.4
8.	Kurodai	Chrysophris hasta........................	0.3 —0.4
9.	Isaki	Prystipoma japonicum..................	0.2 —0.3

All these fishes had been boiled (nisakana), except No. 5, from which the raw flesh had been separated. Of the refuse an equal number of heads, vertebræ, and tails of each species were made air dry in a water stove and reduced to a fine powder, in which the organic matter, total ash, nitrogen, phosphoric acid, lime, and magnesia was determined in the usual way. The results were as follows:—

In 1000 parts of the fresh materials:

Name.	Water.	Organic matter.	Ash.	Nitrogen.	Phosphoric acid.	Lime.	Magnesia.
Inada	642.5	212.5	146.0	27.6	30.9	58.9	1.0
Aji	582.8	289.2	127.9	29.0	24.8	45.9	1.3
Hirame	686.0	195.4	118.6	20.5	29.3	51.3	0.8
Sawara	643.9	277.5	78.6	22.2	17.2	27.2	0.6
Maguro	706.0	226.3	67.7	23.3	21.5	24.7	0.2
Karei.........	583.5	317.8	99.7	25.7	33.5	34.3	0.8
Kochi	578.4	309.1	111.9	28.3	36.9	38.6	1.3
Kurodai......	474.0	314.3	211.7	35.0	61.5	82.1	1.8
Isaki	382.1	437.6	181.3	36.5	53.1	59.1	1.5
Average	586.4	286.6	127.0	27.6	34.3	46.9	1.0

When these substances were made air dry after expelling the moisture in a water oven, they contained only the following quantities of water: Inada 5.50%, Aji 8.41% Hirame 7.11%, Sawara 12.90%, Maguro 6.73%, Karei 6.72%, Kochi 9.21%, Kurodai 7.11 %, Isaki 7.87 %, being an average of 7.85%. In powdering the air dry substances on a hand mill we did not experience any particular difficulty. Hence the manufacture of a dry handy powder from them would certainly be an easy matter, and profitable too for both the producer and consumer, since on the one side the raw material is very cheap* and, on the other, farmers are not in the habit of using raw fish refuse in a rational way, they subject them with some water or other fluids to putrefaction in tanks and apply as manure only that portion which dissolves. The solid matters left after putrefaction, which consist chiefly of the bones are thrown away, probably because the farmers are accustomed only

---

* 1 *ka* = about 12 kuwamme cost at present only 10 Sen

to distribute the solid manure (compost) by hand and would run the risk of hurting and infecting themselves, if fish bones were contained therein. The finely powdered material, for which a fermentation in the compost bed must likewise be recommended, would, of course, admit of the application of the whole refuse and have an effect far superior to the present mode of utilization. Its composition, calculated from the average results of the above analyses would be, as follows :—

Moisture	7.85 %
Organic matter	63.86 ,,
Ash	28.29 ,,
Nitrogen	*6.15* ,,
Phosphoric acid	*7.64* ,,
Lime	10.45 ,,
Magnesia	0.22 ,,

III. Shells of Sea-Turtle.

The specimen which was analyzed in our laboratory came from the Ogasawara (Bonin) Islands where abundance of seaturtle (Chelonia cephalo) are reported to be caught and to be a common article of food. The shells, already broken up into large pieces, were about 2-3 centimeters thick and offered considerable resistance to reduction to a fine powder, owing to a tough skinnyt issue which coated their inner side. After crushing and grinding the sample, the skinny portion was sifted off from the hard bone-like granular pieces, which amounted to 85.7 % of the total air dry shells. The two products were separately analyzed and had the following composition :—

	Bony part.	Skinny part.
Moisture	9.3 %	15.5 %
Organic matter	43.3 ,,	58.7 ,,
Ash	47.4 ,,	25.8 ,,
Nitrogen	*4.88* ,,	*8.58* ,,
Phosphoric acid	*17.42* ,,	*9.52* ,,
Lime	24.54 ,,	14,40 ,,
Magnesia	1.38 ,,	0.75 ,,

The composition of the entire shells as calculated from these figures, is as follows:—

Moisture	10.2 %
Organic matter	45.5 ,,
Ash	44.3 ,,
Nitrogen	*5.55* ,,
Phosphoric acid	*16.30* ,,
Lime	21.03 ,,
Magnesia	1.29 ,,

According to these results, turtle shells very much resemble the bones of the higher animals; they are richer in nitrogen than the latter, but the composition of their ash is almost identical with that of bone ash. As they can be reduced, after a preparatory treatment with steam, and with the help of appropriate mills, to a sufficiently fine powder, they deserve to be collected and applied as manure in the same way as bones. They may probably also serve for the manufacture of animal charcoal.

IV. Various Sea Animals.

Near the sea a number of marine animals are used as manure, especially several kinds of small crabs (kani),

shrimps, various species of Holothuriæ and star fishes. Of these we have analyzed only three specimens, viz.:

1) Holothuria sp? (Mumeboshi) in the air dry state, from Yamaguchi prefecture.

2) Holothuria sp? (Ishiko) the so called sea cucumber, in the air dry state, from Okayama prefecture.

3) Star fish (hitode), small variety, in the fresh state, from Hiroshima prefecture.

The percentage composition was found to be as follows:

	Mumeboshi.	Ishiko.	Hitode.
Water	9.95	8.44	32.68
Organic matter	33.18	35.75	20.87
Ash	13.69	43.94	43.37
Sand	43.18	13.87	3.08
Nitrogen	*2.08*	*5.31*	*1.41*
Oil	2.13	4.89	—
Potash	*0.71*	*0.68*	*0.08*
Soda	3.40	3.49	1.70
Lime	0.99	17.17	21.90
Magnesia	0.22	2.03	0.45
Ferric oxide	3.56	0.55	0.72
Phosphoric acid	*1.65*	*0.71*	*0.61*
Sulphuric acid	0.10	0.99	0.08
Silica	—	0.65	—
Chlorine	3.56	1.29	6.13
Carbon dioxide	—	15.06	17.30

Of these three, the sea cucumber (ishiko) has the highest manurial value on account of its considerable content in nitrogen. Mumeboshi and hitode are nearly equally rich

in this vegetable nutrient, so far as the composition of the dry matter is concerned, whereas the proportion of phosphoric acid and potash is rather inconsiderable in all three kinds of manure. The sea cucumbers and star fishes are, moreover, distinguished by a large content (30—40 %) of calcium carbonate, which, as it is intimately mixed with some organic matter, will readily come into effect in the soil.

V. Rice Brans.

For comsumption in the country itself the rice is cleaned (whitened) invariably by means of wooden mortars and hammers which yield a finer product and less broken grains than the mills generally applied in foreign countries or for the rice destined for exportation from Japan. Frequently a slight proportion of sandy materials is mixed with the grain in order to facilitate the process of cleaning.

For the purpose of getting a reliable average result for the composition of the bran, 100 grms. of each of 7 specimens from the following places, resp. provinces: Ise, Mito, Etchiu, Mino, Nambu, Tokyo and Bushiu, were mixed and analyzed by Mr. *T. Yoshii.* All the 7 kinds of bran were purchased on condition that no sandy materials had been used in whitening. The composition of the mixture was as follows:—

	Air dry substance.	Dry matter.
Moisture	11.33	—
Crude protein	13.01	14.67
Fat	15.15	17.08
Crude fibre	6.83	7.70
Nitrogen free extract	41.22	46.50
Ash free from C and CO_2	8.38	9.45
Sand	4.08	4.60

In 100 parts of the ash free from sand there was found:

Potash	16.74
Soda	0.95
Lime	0.95
Magnesia	15.28
Ferric oxide and alumina	3.40
Phosphoric acid	45.14
Sulphuric acid	0.12
Silica	16.84
Chlorine	trace.

Long experience has taught also in Japan that rice brans are an excellent fodder, but still many farmers apply them as a manure, probably because they are not familiar with any rational method of collection and application of farm-yard manure, and also because they frequently do not keep any live-stock. The manurial value of these brans is illustrated from the following figures, which give the composition per mille of the air dry substance:

Moisture	113.3	Magnesia	12.8
Ash	124.6	Ferric oxide	2.8
Nitrogen	*20.8*	Phosphoric acid	*37.8*
Potash	*14.0*	Sulphuric acid	0.1
Soda	0.8	Silica and sand	54.9
Lime	0.8	Chlorine	trace.

The ratio between nitrogen and phosphoric acid is, according to these figures, just in harmony with the demands of ordinary cereal and root crops, and as the brans also undergo decomposition in the soil with ease, their effect will generally be good.

VI. Oil-cakes from the Manufacture of Vegetable Wax.

In the manufacture of vegetable wax from the berries of Rhus succedanea and vernicifera two different sorts of oil-cakes are obtained in the following way: The berries freed from the stems are treated in a mortar with a heavy hammer until the flesh forms a coarse powder and is entirely separated from the small hard kernels. The whole mass is then steamed for a short time and pressed, in a common oil press while still hot, whereupon the resulting cakes are again broken up and the kernels separated from the powdered flesh with the help of sieves. The kernels are then heated on a pan and ground on stone mills to a fine mass, of which a small part is mixed with the powdered flesh and subjected to a second pressing. The cakes thus obtained are called "*haje dama.*" The other portion of the ground kernels is steamed and separately pressed, whereby cakes are obtained which are called "*mameko dama.*"

Specimens of these cakes which had been obtained from Rhus succedanea at Wakayama, were analyzed in our laboratory by Mr. *E. Yoshida.* Their composition was found to be, as follows:

	Haje dama.	Mameko dama.
Moisture	15.17 %	11.58 %
In the dry matter:		
Crude protein	7.25 ,,	26.75 ,,
Fat	14.20 ,,	17.45 ,,
Crude fibre and nitrogen free extract.	75.17 ,,	50.83 ,,
Ash, free from C and CO_2	3.38 ,,	4.97 ,,
(Total nitrogen)	(1.16),,	(4.28),,

In 100 parts of the pure ash :

Potash	27.02 %	24.79 %
Soda	14.12 ,,	1.80 ,,
Lime	19.51 ,,	11.07 ,,
Magnesia	9.41 ,,	12.68 ,,
Ferric oxide	1.31 ,,	0.94 ,,
Phosphoric acid	14.81 ,,	39.16 ,,
Sulphuric acid	4.01 ,,	5.06 ,,
Silica and sand	9.15 ,,	5.78 ,,
Chlorine	1.02 ,,	0.31 ,,

Both sorts of cakes are still very rich in oil owing partly to the insufficiency of the presses employed, but chiefly to the cooling of the mass while it is being pressed. A part of the so called wax, which has a high melting point, thus solidifies and cannot be obtained.

At present these cakes are generally applied as a manure to paddy fields, but those from the kernels might probably be quite suitable as food for cattle and, in small proportions, also for horses, as they are rich in protein and fat. The manurial value is shown by the following figures which give the composition of 1000 parts of the air dry substance :

	Haje dama.	Mameko dama.
Water	151.7	115.8
Nitrogen	*11.6*	*42.8*
Ash	28.5	48.6
Potash	*7.7*	*12.1*
Soda	4.0	0.9
Lime	5.6	5.4
Magnesia	2.9	6.2
Ferric oxide	0.4	0.5
Phosphoric acid	*4.2*	*19.0*
Sulphuric acid	1.3	2.5
Silica and sand	2.6	2.8
Chlorine	0.3	0.2

As we might have expected, the cakes of the kernels proved to be much more valuable than those which result chiefly from the flesh. The former are similar, but somewhat inferior to rape cakes, the latter are not much better than the straw of leguminous plants. Both require a preparatory decomposition in the compost bed before application.

VII. Tea Seed Cakes.

The seeds of the tea plant are sometimes collected for their oil of which they contain in the dry matter 37.4 %. It appears that the production of seeds is rather scanty, if the plantations are properly treated, and that a noticeable crop of them is only obtained at the expense of the leaves, if the shrubs are allowed to be impaired by weeds.

A specimen of cakes from the pressing of the oil was analyzed by Mr. *J. Sawano* and was composed as follows :—

Water	10.99 %	Lime	0.22 %
Organ. matter	82.76 ,,	Magnesia	0.35 ,,
Ash and sand	6.25 ,,	Ferric oxide	0.78 ,,
Nitrogen	*2.13* ,,	Phosphoric acid	*0.54* ,,
		Sulphuric acid	0.16 ,,
Potash	*1.99* %	Silica and sand	1.73 ,,
Soda	*0.08* ,,	Chlorine	trace

The tea seed cakes are accordingly much inferior to the other ordinary kinds of oil cakes, which are far richer in nitrogen and phosphoric acid. Owing to their extremely bitter taste they cannot be utilized as cattle food.

VIII. Saké Cakes.

In the manufacture of rice wine (saké), of which whitened rice constitutes the only raw material, some parts

of the steamed grain are left undissolved or unfermented, and these when freed from alcoholic liquor by pressing, represent the saké cakes. The latter are not frequently applied directly as manure, but usually first serve for pickling radishes (daikon) to which they infuse a good taste owing to their content of saké, which has not been removed by pressing. The cakes which consist of a soft mass are mixed for this purpose with much common salt and placed in tubs, the radishes which had been previously dried as much as possible in the air, are imbedded in the mass, and a lid with heavy stones is put on the top. When the fermentation of the radishes is complete, the cakes are applied to the fields.

Sometimes the alcohol, left in the cakes after pressing is gained by distillation in a current of steam. As the soft cakes would, however, prevent the steam from passing freely through them, they are usually mixed before distillation with some rice hulls (about 1 part of hulls for 10 parts of cakes by weight). The remainders thus obtained are known as *shochiu cakes* (alcohol cakes) and are directly utilized as manure.

The fertilizing properties of these two kinds of manures can be approximately deduced from analyses of the original cakes left after pressing. Mr. *Y. Mori*, assistant in the laboratory, collected 5 specimens of such cakes, viz. 2, called Nada, 2 Ise and 1 Jimawari, made a portion of each air dry and mixed for the analyses equal quantities of the air dry samples. The proportion of moisture was in Jimawari 45.74°/₀, in the other 61.25, 62.87, 63.10 resp. 60.74°/₀ ;— an average of 58.74°/₀. As one of the samples proved accordingly rather dry, and the other 4 exhibited nearly the same degree of moisture, we had better assume the average of the latter 4 samples e. g. 62.0°/₀ of moisture as the content of ordinary fresh saké cakes.

The mixture of equal parts of the fresh specimens contained in 100 grms. 5.66 grms. of alcohol.

From the analysis of the mixture of equal quantities of air dry matter we obtained the following results :—

	Per mille, fresh cakes.	Per cent. dry matter.
Water	620	—
Crude protein	180.9	47.60
,, fat	42.2	11.11
,, fibre	16.3	4.29
Nitrogenfree extract	34.6	35.43
Ash	6.0.	1.57
Total nitrogen	*28.94*	7.616
Albuminoid nitrogen	21.88	5.758
		In 100 p. of ash.
Potash	*0.72*	12.06
Soda	0.24	4.07
Lime	0.14	2.41
Magnesia	0.28	4.74
Ferric oxide	0.23	3.76
Phosphoric acid	*2.69*	44.80
Sulphuric acid	trace	trace
Silica and sand	1.68	28.02
Chlorine	trace	trace

Saké cakes are accordingly very rich in nitrogen and not so poor in phosphoric acid as might have been expected on account of their extraction with water during the fermentation. Mixed with hulls and freed from alcohol by distillation by which also the yeast is killed, they form a suitable fodder for cattle and hogs. In the salted condition, however, after serving for the preparation of pickled radishes, they can only be used as manure, as the extraction of the excessive salt would in this case greatly diminish the nutritive value of the cakes by removing likewise soluble nitrogenous and nitrogenfree compounds which are doubtless formed in the course of storing the tubs.

IX. Shoyu Cakes.

Shoyu, a sauce widely consumed in this country is the product of the very slow fermentation of a mixture of boiled crushed soy beans, roasted ground wheat, wheat meal, *koji* (steamed rice, on which a special fungus is brought up), common salt, and water. After one or several years' fermentation the dissolved portion, the sauce, is filtered off and the remainder pressed, which process is sometimes repeated after the addition of a little water. The solid moist mass left represents the shoyu cakes, which are commonly utilized as manure, sometimes also as food for hogs.

A mixture of equal quantities of 5 specimens was analyzed by Mr. *Y. Mori* and the results obtained were as follows :

	Per mille, fresh cakes.	Per cent, dry matter.
Water	536.0	—
Crude protein	126.0	27.15
,, fat	136.8	29.49
,, fibre	67.4	14.53
Nitrogen free extract	66.5	14.30
Ash	67.3	14.50
Total nitrogen	20.16	4.344
Albuminoid nitrogen	17.27	3.721
		In 100 p. of ash :
Potash	8.84	13.14
Soda	22.02	32.72
Lime	1.82	2.71
Magnesia	2.92	4.34
Ferric oxide	0.84	1.24
Phosphoric acid	2.32	3.45
Sulphuric acid	1.62	2.41
Silica and sand	1.12	1.67
Chlorine	33.07	49.15

We learn from these figures that a very considerable proportion of the albuminoids applied in the manufacture of shoyu have been rendered soluble, resp. converted into soluble substances and that in spite of the richness of the raw materials (soy brans) the resulting cakes are poorer in nitrogenous bodies than the saké residues, obtained from grain so extremely poor in nitrogen. Nevertheless the soy cakes are still quite a valuable manure, and may also be used as a cattle food, since they still contain a comparatively large proportion of crude protein and fat. Owing to their richness in common salt, however, which amounts to nearly 5 % in the fresh cakes, they are unfit to form a large part of the daily rations. Perhaps it may be possible to extract the greater part of the salt with cold water without running the risk of removing at the same time any essential part of the valuable albuminoids, but even if so, care is to be recommended in the feeding, because the fungi contained in the cakes might affect the digestive canal. Researches on the latter two subjects appear to be needed before definite proposals can be made.

The analysis furthermore indicates that the dry matter of the cakes contains about 30% of crude fat. Researches on the composition of the latter have shown that it contains 94.5% of fatty acids insoluble in water, of a melting point of 24° C. It may be well worth trying whether from the dried residues oil might not be easily gained and whether the product might not find useful applications.

X. Tofu Cakes.

Tofu, e. g. bean curd essentially consists of legumin, and is prepared from soy beans, which are steeped in water, finely ground on stone mills and extracted with much water. The solution of legumin thus obtained is heated to boiling, filtered

after cooling, and precipitated with the brine that drains off from the crystals of common salt during the preparation of the latter from sea water. The precipitate, after being pressed in wooden frames represents the tofu, a common human food in China and Japan.—The portion left undissolved of the beans, called *tofu kasu* is chiefly used as food for domestic animals, but is sometimes also consumed by the poorer classes or used as manure.

An analysis of such cakes, by Mr. *J. Sawano*, gave the following results (fresh substance) :—

	Per cent.		Per mille.
Water	85.74	Potash	*1.71*
Crude protein	3.82	Soda	0.07
Fat	1.44	Lime	0.97
Crude fibre	3.15	Magnesia	0.40
Nitrogenfree extract.	5.38	Ferric oxide	0.10
		Phosphoric acid	*1.20*
Ash	0.47	Sulphuric acid	0.12
		Silica and sand	0.12
Total nitrogen	*0.611*	Chlorine	0.01
Albuminoid nitrogen	0.024		

As the dry matter of the cakes is still rich in protein (26.7 %) and fat (10.3 %), they deserve, of course, to be more recommended as a food for cattle and hogs, than as a manure for direct application.

XI. Residues from the Manufacture of Indigo.

The most important among the dye stuffs used in Japan is the indigo produced almost entirely from Polygonum tinctorium. Only the leaves of this plant, which is widely cultivated in this country, are used for the manufacture, while the stems are mostly applied for composting, or made into ash and used as a manure. The leaves are exposed to

the sun for a few hours, afterwards packed in straw bags and kept for a time. They are then moistened with some water, spread out on, and covered with, other mats for a few days, which operations are repeated from 9 to 25 times during a period of from 2-3 months. After this fermentation the leaves are reduced in a mortar to a kind of paste which is then formed into balls of 3-4 inches diameter. These balls, with an addition of potash lye from wood ashes and slaked lime and sometimes rice wine, bran, or starch sugar (amé), form the material used by dyers in the steeping vat. The residues left undissolved or depositing from the fluid are sold as manure.

The stems and leaves of a specimen from Miyodo-gori, Tokushima prefecture were analyzed by Mr. *T. Yoshii*, with the following results: The whole plant excl. roots contained 83.59 % of water and the dry matter was made up of 62. 1 parts of stems and 37.9 parts of leaves. In the air dry matter there was found:

	Leaves.	Stems.
Water	17.74 %	19.65 %
Organic matter	70.56 ,,	73.17 ,,
Total ash	11.70 ,,	7.18 ,,
Total nitrogen	*3.742* ,,	*1.176* ,,
Potash	*1.612* ,,	*2.032* ,,
Soda	0.116 ,,	0.496 ,,
Lime	3.040 ,,	1.331 ,,
Magnesia	1.503 ,,	0.591 ,,
Ferric oxide	0.364 ,,	0.080 ,,
Mangano-manganic oxide	0.146 ,,	0.043 ,,
Phosphoric acid	*0.705* ,,	*0.542* ,,
Sulphuric acid	0.381 ,,	0.295 ,,
Carbon dioxide	1.890 ,,	1.080 ,,
Silica and sand	1.462 ,,	0.337 ,,
Chlorine	0.398 ,,	0.256 ,,

Percentage composition of the ash :

	Leaves.	Stems.
Potash	13.78	28.30
Soda	0.99	6.91
Lime	26.00	18.54
Magnesia	12.85	8.23
Ferric oxide	3.11	1.11
Mangano-manganic oxide.	1.25	0.60
Phosphoric acid	6.03	7.55
Sulphuric acid	3.26	4.19
Carbon dioxide	16.15	15.04
Silica and sand	12.50	4.69
Chlorine	3.40	3.57

The ash prepared from the stems has accordingly little more than twice the value of ordinary wood ashes. When used on the farm itself, it is, of course, not advisable to incinerate them, unless the fields are suffering from an excess of humus and wetness.

The residues left after dissolving the indigo in the dyer's vat, constitute a deep blue, soft mass, in which on an average of 5 specimens, analyzed by Mr. *Y. Mori*, the following composition was found :

	In the fresh substance.	In the dry matter.
Water	44.62	—
Organic matter	18.48	33.37
Ash*)	36.90	66.63
Nitrogen	*0.632*	1.141
		In 100 p. of ash*) :
Potash	*0.47*	1.28
Soda	*0.27*	0.73
Lime	10.62	28.78
Magnesia	0.06	0.16
Ferric oxide	1.47	3.98

*) Not free from carbon dioxide.

	In the fresh substance.	In 100 p. of ash.
Alumina	1.42	3.85
Phosphoric acid	*0.92*	2.49
Carbon dioxide	3.67	9.94
Silica and sand	17.98	48.72
Chlorine	0.02	0.06

As these figures show, the indigo residues have only a low manurial value; they chiefly consist of a sandy mass containing a considerable quantity of calcium carbonate but only very little of nitrogen, phosphoric acid, and potash, and will act chiefly as an indirect manure by their content of lime.

The percentage of water in the residues is subjected to variations, we found in the 5 specimens a minimum of 37.3, a maximum of 57.9% of moisture.

XII. Astragalus lotoides, a Green Manure.

This plant, known in the country as *genge*, grows spontaneously on paddy land in many places, covering the whole area of the fields and flowering at the time when the farmers commence to prepare the latter for the cultivation of rice. A specimen of the plant cut in blossom and dried in the air was sent to us from Gifu prefecture and analyzed by Mr. *Y. Mori*. It had the following composition:

	Per mille, fresh substance.	Per cent. dry matter.
Water	820	—
Crude Protein	30.26	16.81
,, fat	10.89	6.05
,, fibre	56.92	31.62
Nitrogenfree extract	72.14	40.08
Ash, free from CO_2 and sand	9.79	5.44
Total nitrogen	*4.84*	2.689
Albuminoid nitrogen	3.85	2.410

	Per mille, fresh subst.	In 100 p. of ash.
Potash	3.77	38.44
Soda	0.19	1.90
Lime	2.38	24.28
Magnesia	0.86	8.84
Ferric oxide	0.22	2.25
Phosphoric acid	0.90	9.19
Sulphuric acid	0.21	2.10
Silica and sand	0.75	7.63
Chlorine	0.59	6.06

As the Astragalus belongs to the papilionaceæ, the majority of the nitrogen found in it must have been assimilated in the form of free nitrogen, and the field must have consequently become richer in this valuable nutrient than it would have been without the growth of this plant. The utilization of the Astragalus as a green manure for paddy rice deserves to be strongly recommended, as a good supply of nitrogen to the crop very materially increases the yield. Hence attempts should be made to raise the plant from seeds in all places where no attention has hitherto been paid to it by the farmers. In all cases, whether it is already indigenous or newly introduced by seeds, the Astragalus should not be left without manure, for which purpose wood ashes and phosphates are particularly suited. The manure thus given is not lost but partly remains in the soil, partly passes into the plant which would thus be enabled to thrive vigorously and to take up more free nitrogen than it could do without a supply of its essential mineral nutrients.

XIII. Sea Weeds (Laminaria Japonica).

These sea weeds are largely collected especially on the northern shores and serve partly as human food, partly as

manure. A sample of a shipment brought to Tōkyō from Yezo already in a slightly wilted condition was analyzed in the laboratory by Prof. *M. Takeo.* It contained, per cent of the fresh substance :

Water	50.75
Organic matter	14.21
Sand	21.94
Common salt (mechanically separated)	3.36
Other mineral matters	9.74
Nitrogen	*0.352*
Potash	*1.630*
Soda	3.412*
Lime	0.726
Magnesia	0.043
Ferric oxide	0.052
Phosphoric acid	*0.122*
Sulphuric acid	0.086
Silica	1.289
Chlorine	3.063*
Total common salt	8.41

As this kind of sea weed is not very rich in vegetable nutrients, it would hardly pay the expense of transportation to distant places. Its application to the land near the shores is, of course, quite rational, but, as it is rich in common salt, it may be slightly washed with water before it is used.

* The mechanically separated salt is not included in these figures.

XIV. Wood and Straw Ashes.

The ashes resulting from charcoal and wood fire as well as specially prepared straw ashes represent an article of trade in the larger Japanese towns and are widely applied as manure. A mixture of 5 specimens of either kinds bought in Tokyo was analyzed by Mr. *M. Nagaoka*, assistant in the laboratory. The percentage composition was as follows :—

	Wood ash.	Straw ash.
Water	4.13	3.09
Carbon	1.22	5.80
Mineral matters	94.65	91.11
Potash	*11.68*	*4.49*
Soda	1.68	0.90
Lime	30.27	2.25
Magnesia	6.54	1.84
Ferric oxide and alumina	2.67	1.35
Phosphoric acid	*3.94*	*2.09*
Sulphuric acid	1.49	0.19
Carbon dioxide	11.20	—
Silica and sand	22.45	74.00
Chlorine	0.58	1.13

The wood as well as the charcoal used in this country as fuel is chiefly made from deciduous trees (oak and chestnut), while for the preparation of the straw ashes most kinds of

straw and stalks are applied. As might have been expected, the ashes of wood are far more valuable as manure, than those obtained from straw.

XV. Various Kinds of Straw and Chaff.

These materials are used as litter for domestic animals, and for the preparation of compost and ashes. The results of analyses are given in the following tables:

	Oryza sativa.		Oryza sativa.		Oryza sativa.	Avena sativa.	Hordeum vulgare.	Panicum miliaceum.	Panicum frumentaceum.	Panicum italicum.
	Straw*. Paddy rice.		Straw*. Upland rice.		Chaff. Paddy rice.	Straw. Oat.	Straw. Barley**.	Straw. Millet(kibi).	Straw***. Millet(hiye).	Straw. Millet(awa).
Water	10.27	14.06	11.69	18.30	9.31	—	—	—	—	—
In 100 p. of dry matter:										
Crude protein	5.15	3.99	6.65	7.47	4.56	6.30	5.00	4.09	10.63	6.76
„ fat	2.12	2.92	3.60	1.73	0.77	2.29	1.44	4.27	2.58	1.57
„ fibre	41.86	40.76	41.28	44.07	48.09	46.52	48.96	43.84	41.79	38.65
Nitrogenfree extract.	44.11	42.72	41.31	35.56	28.15	37.37	36.52	39.85	35.21	43.66
Ash	6.76	10.31	7.16	11.17	18.43	7.52	8.08	7.96	9.79	9.36
Total nitrogen	0.825	0.639	1.063	1.195	0.730	0.923	0.801	0.655	1.70	1.081
Albuminoid	0.722	0.565	0.840	0.711	—	—	0.736	—	1.59	0.766
In 100 p. of ash:										
Potash	10.88	12.31	9.61	10.55	3.00	30.25	23.59	31.12	16.90	16.24
Soda	1.61	0.57	1.17	1.77	1.66	4.17	5.63	1.87	2.53	2.83
Lime	3.41	3.72	1.80	6.12	0.42	2.97	5.88	3.62	5.38	6.55
Magnesia	2.57	2.54	1.52	4.56	1.04	2.43	1.10	9.18	9.98	4.37
erric oxide	0.63	1.50	0.64	0.79	0.36	0.77	0.96	1.55	1.63	1.95
Phosphoric acid	1.44	1.59	0.90	1.73	1.20	3.34	1.91	3.00	5.13	3.65
Sulphuric acid	1.09	1.82	0.78	1.64	trace	1.10	1.65	3.09	6.90	3.02
Silica	77.00	73.30	80.66	70.94	93.13	50.19	48.58	33.43	41.66	55.28
Chlorine	2.11	3.10	2.88	3.83	0.01	5.37	14.95	13.81	9.38	5.43

* Completely dead ripe.

** Winter grown barley.

*** Cut rather early.

Botanical name:	Eulalia Japonica.	Bambusa Sasa.	Convolvulus Batatas.	Solanum melongena.	Gossypium herbeceum.	Arachis hypogaea.	Lespedeza cyrtobotrya.	Pueraria Thunbergiana.	Vicia cracca.
English resp. Japanese name*:	Kaya (1.	Bamboo grass. Sasa.	Batatas (2.	Egg plant (3. nasu.	Cotton (4.	Earthnut (5.	Hagi (6.	Kudzu (7.	Kusa fuji (8.
Water	18.10	14.05	85.39	79.20	66.76	77.10	15.94	16.00	17.64
In 100 p. of dry matter:									
Crude protein	8.26	12.55	11.44	10.16	4.69	16.00	17.51	20.83	16.40
,, fat	2.56	2.24	6.60	3.36	3.55	4.27	4.37	3.10	2,60
,, fibre	40.44	41.09	29.01	32.10	59.72	20.11	34.45	32.74	31.76
Nitrogenfree extract	44.17	37.93	46.63	44.52	21.54	50.01	36.66	34.72	45.80
Ash	4.57	16.19	6.28	9.86	10.89	7.05	7.01	8.61	3.84
Total nitrogen	1.323	2.008	1.831	2.824	0.75	2.56	2.801	3.33	2.624
Albuminoid ,,	1.071	1.600	1.483	0.918	0.44	1.96	2.153	2.72	——
In 100 p. of ash:									
Potash	22.84	6.65	39.13	40.38	9.67	20.75	17.19	33.42	33.90
Soda	1.47	1.13	5.19	7.77	6.35	3.83	9.52	5.35	8.78
Lime	10.70	2.24	21.25	22.56	10.50	40.05	31.55	3.26	21.84
Magnesia	1.28	1.82	8.17	8.12	17.13	13.79	4.03	6.03	5.94
Ferric oxide	0.84	0.65	3.90	1.31	9.12	1.78	2.42	1.81	2.73
Phosphoric acid	4.54	1.74	5.36	7.24	14.92	5.87	6.02	8.12	9.67
Sulphuric acid	3.43	1.04	7.99	2.76	12.43	3.79	2.43	2.78	2.66
Silica	49.54	82.81	3.87	3.44	9.82	3.89	25.60	8.58	4.75
Chlorine	3.67	2.15	7.29	6.46	8.84	6.02	1.64	10.54	6,80

According to these analyses the hay made from the earthnut plant, *hagi*, *kudzu* and *kusa fuji* constitutes a very nutritious fodder for the farm animals, while the vines of the batatas and the stems of the cotton and egg plant cannot be used for this purpose and are, in fact, mostly burnt directly on the field or made to compost. Of the wild plants, *kaya*, *sasa*, *kudzu*, *hagi*, etc., which grow on uncultivated land, are applied as green manures chiefly to paddy fields, or in the preparation of compost ; in later stages of growth, in autumn, they are chiefly used as ash.

1) Hay, cured before blossom. 2) Vines taken when the tubers were ripe. 3) Stems with a few leaves, cut when the fruits had been harvested. 4) Stems, almost destitute of leaves, cut when the cotton was ripe. 5) Still fully green, when the nuts were harvested. 6) Hay, cut at the end of June. 7) Vines cut in the beginning of September. 8) Hay cured before blossom.

XVI. Leaves and Grasses from Forests.

Nearly every winter the forests are deprived by the farmers of the leaves cast off in autumn, and of the dry grasses, of which materials ash and compost are prepared for manuring purposes. Specimens of *dry leaves of oaks* (Quercus serrata, *kunogi,* and Quercus crispula, *nara*) *and pine* (Pinus Matsu, *matsu*), as well as the *straw of Eulalia japonica* (*kaya*), *Imperata arundinacea* (*chigaya*) and bamboo grass (*sasa*) collected by Dr. E. Grasmann, professor in the college, and kindly delivered to us were analyzed by Mr. *M. Nagaoka.* Their composition was, as follows (per mille :

	Oak leaves.	Pine leaves.	Grasses (straw).
Moisture	132.8	119.2	108.6
Organic matter	822.6	870.3	815.0
Ash	44.6	20.5	76.4
Nitrogen	*10.7*	*4.3*	*5.4*
Potash	*1.98*	*0.42*	2.25
Soda	0.99	0.36	0.72
Lime	17.80	5.93	4.31
Magnesia	3.48	1.69	0.24
Ferric oxide and alumina.	0.88	1.78	1.12
Phosphoric acid	*1.75*	*2.95*	*0.90*
Sulphuric acid	0.60	0.51	0.80
Silica	14.69	5.95	64.92
Chlorine*	—	—	—

The manurial value of these materials is, of course, not great. By taking them away from the forests and thus preventing that on the soil a good layer of humus is formed, the forests are certainly more injured than the fields are profiting from that manure.

* Not determined.

The crude ash prepared by simple incineration of the above materials was composed as follows:—

	Oak leaves.	Pine leaves.	Grasses (straw).
	%	%	%
Potash	*4.40*	*2.04*	*2.86*
Soda	2.21	1.74	0.92
Lime	39.48	28.56	5.48
Magnesia	7.72	8.15	0.31
Ferric oxide and alumina	1.95	8.57	1.43
Phosphoric acid	*3.88*	*14.24*	*1.14*
Sulphuric acid	1.33	2.45	1.02
Silica and sand	32.57	28.70	82.60
Chlorine*	—	—	—
Carbon dioxide	4.15	1.65	0
Carbon	1.03	1.00	2.81
Total ash in the air dry substance.	4.51	2.08	7·86

The ash from the pine leaves ranks accordingly first, next comes that from oak leaves, while the ash from the grasses (straw) is the poorest.

When we review the results of the analyses on the preceding pages and also those contained in No. 3 of the Bulletins of this College, we find that there exist among the Japanese fertilizers many which, with due regard to their composition as well as copiousness, are well suited to supply the demand of the cultivated land for nitrogen. An improved and extended system of taking marine animals, a more extended cultivation of leguminous plants, especially the introduction of leguminous forage crops for the working animals, and the large supply of green manures from the uncultivated land, would render the country independent from without for a supply of nitrogenous fertilizers. *Con-*

* Not determined.

centrated phosphatic manures of frequent or copious occurrence are, however, conspicuous for their absence. Hence the importation of fertilizers of this sort, lately commenced in several places, deserves the unanimous approval and support of all those who are interested in the welfare of the farming classes. With regard to potash manures, though many soils are still sufficiently rich in this nutrient, yet trials as to its efficacy on various soils should not be neglected.

東京農林學校
學術報告
第五號

Imperial College
OF
AGRICULTURE & DENDROLOGY.
KOMABA, TOKYO, JAPAN.

BULLETIN NO. 5.

Researches
on the Distribution of Vegetable and Animal Nutrients over
the Products obtained from Rice by Whitening

AND

on the Manufacture, Composition, and Properties of "Koji."

COMMUNICATED BY

DR. O. KELLNER,
Professor of Agricultural Chemistry.

明治二十二年六月
TOKYO, JAPAN, JULY, 1889.

Researches on the Distribution of Animal and Vegetable Nutrients over the Products obtained from Rice by Whitening (Cleaning),

CARRIED OUT IN CONJUNCTION WITH

S. Tanaka and F. Kobayashi

BY

Dr. O. Kellner.

All the rice that is used as human food or in the manufacture of *sake* (rice wine), *shochiu* (alcohol), *miso* (a food adjunct), or *shoyu* (a sauce), is first subjected to the process of whitening or cleaning, by which the bran is separated from the grain. This is effected sometimes by water power, usually however by manual labour. In the latter case the grain is placed in a conically shaped wooden mortar sunk in the ground, and a heavy wooden hammer supported upon a fulcrum is arranged in such a way that, when the workman presses down by his body-weight the end of the lever away from the mortar and then removes the pressure, the heavy end of the lever with the hammer falls by its own weight into the mortar deeply entering it and causing the grains to rub against one another, whereby the testa and the majority of the germs are scraped off. After every 4-5 hours' pounding the grains are sifted and retransferred into the mortar, until after 16-20 hours the cleaning is finished. The pounded mass is separated by sieves and fan mills into three portions, the whitened grain, the broken grain, and the bran.

According to practical observations, 87-95 parts of whitened rice are obtained from 100 parts of hulled grain by volume, if the rice is destined for consumption, while for manufacturing processes less bran is separated from the grain. I. F. Eijk-

man, who occupied himself with this subject, obtained on a trial—the only one ever made, so far as I know—the following proportions by weight from 100 p. of grain :

89.42 p. whitened rice,
8.75 „ bran,
1.30 „ broken grain,
0.53 „ loss.

Analyses of the rice before and after whitening as well as in the boiled state (*meshi*), have been made by Messrs. S. Tsujioka and M. Saito[2] in the Yokohama Public Laboratory. Two sorts of rice were there examined, viz. Sekitori (from the province of Ise, a superior quality, and Hongoku (from the province of Oshiu) an inferior variety. The percentage composition was, as follows :—

	Sekitori.			Hongoku.		
	Hulled grain.	Whitened grain.	Boiled rice.	Hulled grain.	Whitened grain.	Boiled rice.
Water	13.70	14.27	65.00	13.57	14.13	65.00
Crude protein	8.54	7.66	2.77	5.57	5.56	2.69
Fat	2.04	0.58	0.03	1.32	0.55	0.03
Crude fibre	0.96	2.66	1.04	3.16	3.96	1.05
Starch	71.67	71.16	27.40	73.43	72.37	27.82
Dextrin and sugar	1.93	2.21	2.50	1.17	1.98	2.31
Ash	1.32	1.23	0.50	1.44	1.32	0.54

These figures show that the whitened rice is poorer in albuminoids, fat, and ash, than the raw hulled grain, a fact already known from the analyses of raw and cleaned specimens of rice taken from different sources. It is, however, somewhat striking in the above results that the whitened

[1] Yeisei Shiken Jho, 1886.
[2] Mainichi Shimbun, 1886, March 6th.

grain contains in its dry matter less resp. only a little more starch than the raw rice, whereas we might have expected, on account of the general richness of the bran in albuminoids, fat, and fibre, that in the grain freed from the bran there would be found less fibre and more of carbohydrates than in the original hulled rice.

The subject under discussion was experimented on in our laboratory by Mr. *S. Tanaka*, who, under his immediate superintendance, had 23.929 kilograms of the famous rice from the province of Mino, whitened by manual labour. The products were weighed soon after the cleaning, and were found to contain, per cent of the grain applied:

Whitened Rice	91.05%
Bran	7.37 ,,
Broken grain	1.69 ,,
Total	100.11 ,,

The slight increase of the weight (0.11%) must certainly be due to water, attracted by the powdered materials from the air.

A second trial was made by Mr. *F. Kobayashi*, who applied a medium sort of rice, grown in the province of Echiu, and who obtained from 100 parts of raw grain:

Whitened grain	91.92%
Bran	7.16 ,,
Broken grain	0.50 ,,
Hull, waste products, etc.	0.30 ,,
Total	99.98 ,,

The results of the two trials very nearly coincide with each other as well as with Eijkman's figures. Calculated for 100 parts of dry matter applied in the form of raw grain, the following quantities were obtained by the cleaning:

	Mino Rice.	Echiu Rice.	Average.
Whitened grain	89.16	90.19	89.68
Bran	7.48	7.22	7.35
Broken grain	1.65	0.60	1.12
Total	98.29	98.01	98.15
Loss..............	1.71	1.99	1.85

The percentage composition of these products was found to be as follows:

	Mino Rice.			Echiu Rice.		
	Raw Grain.	Whitened Grain.	Bran.	Raw Grain.	Whitened Grain.	Bran.
Water...........................	13.42	15.21	12.09	13.65	15.27	13.01
In the dry matter:						
Crude protein.....................	9.40	8.25	17.46	7.98	6.59	17.15
Fat	3.14	1.46	21.48	2.43	0.95	22.36
Crude fibre........................	1.39	0.56	9.11	1.83	0.46	11.29
Starch..............................	84.55	89.02	22.88	84.61	89.79	27.43
Dextrin and glucose			13.62	2.11	1.56	8.41
Other nitrogenfree subst.....			5.58			
Mineral matters	1.52	0.71	9.87	1.04	0.65	13.36
Total nitrogen	1.504	1.320	2.797	1.277	1.053	2.744
Albuminoid ,, ...	1.451	1.290	2.609	—	—	—
Non-albuminoid ,, ...	0.053	0.030	0.185	—	—	—

In spite of the small proportion of bran that is removed by the cleaning the composition of the grain is materially altered by the process, becoming relatively poorer in all ingredients save carbohydrates, which show an increase of 4-5% in the dry matter of the product. The bran, on the other hand, chiefly consisting of the testa and embryo, the tissues of which are extremely rich in albuminoids and fat, contains of every ingredient, carbohydrates excepted, relatively far more than the original rice. It results, moreover, from the above analyses that the composition of the whitened grain is dependent to some extent on that of the original rice. The poorer the hulled grain is in albuminoids and fat, the less is also found in the whitened product.

The following figures illustrate the quantitative distribution of the components of the original grain over the

products, assuming that 100 parts of dry matter were subjected to the cleaning:

	Whitened grain.	Bran.	Broken grain[a]).	Total.	Loss.
A. Mino Rice.					
Crude protein............	7.36	1.31	0.16	8.83	0.57
Fat	1.30	1.61	0.05	2.96	0.18
Crude fibre	0.49	0.68	0.02	1.19	0.20
Nitrogenfree extract ...	79.37	3.15	1.39	83.91	0.64
Ash	0.63	0.74	0.03	1.40	0.12
B. Echiu Rice.					
Crude protein............	5.94	1.24	0.05	7.23	0.75
Fat	0.86	1.61	0.01	2.48	—
Crude fibre	0.41	0.82	0.01	1.24	0.59
Nitrogenfree extract ...	82.39	2.59	0.52	85.50	1.22
Ash	0.59	0.96	0.01	1.56	—

On calculating how much of 100 parts of each organic constituent of the original grain appears in each of the 3 products we obtain the following results:

	Whitened grain.	Bran.	Broken grain.	In the total products.	Loss.
A. Mino Rice.					
Crude protein.....................	78.3	13.9	1.7	93.9	6.1
Fat	41.4	51.3	1.6	94.3	5.7
Crude fibre	35.2	49.0	1.4	85.6	14.4
Nitrogenfree extract	93.9	3.7	1.7	99.3	0.7
B. Echiu Rice.					
Crude protein	74.4	15.5	0.6	90.5	9.5
Fat	66.3	35.4	0.4	102.1	——
Crude fibre	22.4	44.8	0.6	67.8	32.2
Nitrogenfree extract	95.0	3.0	0.6	98.6	1.4
C. Average.					
Crude protein	76.4	14.7	1.1	92.2	7.8
Fat	53.9	43.3	1.0	98.2	1.8
Crude fibre	28.8	46.9	1.0	76.7	23.3
Nitrogenfree extract...........	94.5	3.3	1.2	99.0	1.0

[a] Assumed to have to composition of the original raw grain.

According to these figures there appear of the total crude protein nearly $\frac{2}{3}$, of the fat $\frac{1}{2}$, and of the carbohydrates nearly the whole quantity ($^{19}/_{20}$) in the whitened rice, while in the brans almost half of the total fat and fibre of the original grain is obtained. The dust lost during the cleaning, amounting to only 1.85 % of the whole dry matter applied, seems to consist chiefly of the fine skin (testa) which is rich in fibre and crude protein, but poor in fat.

Before the whitened rice is cooked for consumption it is usually *washed*, by rubbing it between the hands in cold water as long as the water runs off milky. The loss of dry matter caused by this operation amounted in the specimen of Echiu rice to 5.40% of the wholedry matter. After drying the washed grain it had the following percentage composition.

Moisture	17.59%
In 100 parts of dry matter :	
Crude protein	6.25 ,,
Fat	0.39 ,,
Fibre	0.47 ,,
Nitrogenfree extract	92.51 ,,
Ash	0.38 ,,

Comparing these figures with the whitened grain we find that still some crude protein, fat, fibre, and ash had been washed away, whence the proportion of carbohydrates was relatively increased. The loss is doubtless due to the removal of some bran which mechanically adhered to the surface of the cleaned rice.

It remains still to consider the distribution of the principal *mineral matters* over the 3 products obtained by whitening, on which subject though we have not made any direct researches, we are able to throw some light, by means of analyses of the ashes of various specimens of hulled rice and brans. Japanese rice appears to be very poor in mineral substances, containing on an average of 12 analyses made in our laboratory, only 1.15% of pure ash; and the whitened grain is, of course, still poorer, its contents amounting only to 0.5%. In the ash of

hulled rice we found, on an average of 5 complete ash analyses, 22.7% of potash and 51.5% of phosphoric acid, and in that of rice brans (mixture of 7 specimens) 16.7% of potash and 45.1% of phosphoric acid[4] the total amount of ash being 9.45% in the dry matter. Hence there exists:

	Potash.	Phosphoric acid.
In 100 p. of orig. hulled grain......	0.26%	0.59%
In 7.35 p. of bran.....................	0.12 ,,	0.30 ,,
In the whitened and broken grain	0.14 ,,	0.29 ,,

The minute quantity of mineral matters contained in the small proportion of dust (loss) being neglected, we see that by the process of whitening nearly exactly half the amounts of potash and phosphoric acid are gained in the brans, — a fact which has an important bearing on the statics of Japanese agriculture.

[4] Bulletin No. 4 of this college, p. 17.

Researches on the Manufacture, Composition and Properties of "Koji."

BY

Dr. O. Kellner, Y. Mori, and M. Nagaoka.

Koji i.e. steamed rice or barley upon which is developed the mycelium of special fungus plays an essential part in various manufacturing processes peculiar to Japan and China. It is used as a saccharifying substance in the preparation of rice wine (*sake*) and alcohol (*shochiu*) and seems likewise to be the chief active ingredient which brings about the slow fermentation as well in the manufacture of *miso*, a food adjunct very common in Japan, as in the preparation of *shoyu*, a peculiar sauce also largely consumed in the country.

Having regard to the importance of koji in such various and extensive manufacturing branches, it appeared to us desirable to study in detail the chemical processes and changes of the constituents of barley and rice caused by the development of the fungus during the preparation of koji. A few analyses of whitened rice and of the koji obtained therefrom have, it is true, already been made, but they admit only of conclusions about the qualitative changes of the raw material, and do not throw much light on the quantitative proportions to which these alterations may be carried by the fungus. In experimenting on this latter subject we prepared koji from rice and barley in the following way, which is generally adopted in the koji works, and which has already been described by O. Korschelt[1] and R. W. Atkinson[2].

---

[1] Mittheilungen der deutschen Gesellschaft für Natur- und Völkerkunde Ostasiens, 1878, vol. 2, p. 240.

[2] Memoirs of the Science Department, Tōkyō Daigaku (University of Tōkyō), No 6, 1881, p. 5.

The hulled or whitened grain was placed in a tank with some water, and from time to time trodden upon by workmen, the water being frequently changed, in order to remove the fine dust which adhered to the grain. The washed material was allowed to steep under water in the tank for one night, and was then steamed in a large tub provided with a false bottom covered with cloth, and fixed upon an iron boiler in which water was heated to boiling. When the steam passing through the tub had gelatinized the starch and rendered the grains flexible, the material was spread out upon mats and allowed to cool, during which time the workmen rubbed the grains between their hands to prevent them from cohering. When the temperature had fallen to 28°C., a small quantity of the grain was mixed with the spores of a fungus described by Ahlburg under the name of Eurotium Oryzæ, of which only about 2 grms. were applied for about 100 litres of grain. The seeded portion was then uniformly distributed over the whole mass of steamed grain. After this operation we weighed the contents of one whole mat and took a weighed sample for the analysis.—The mats with their contents were then carried into the front part of a sort of cellar where the temperature was a little lower than in the inner parts. After being kept there for 18-20 hours, the steamed grains were spread out at 8 a.m. (on the 2nd day of the whole process) in thin layers upon wooden trays, and carried into the interior of the cellar. Early in the morning (6 a.m. on the 3rd day) the grains, which had become very warm in the meantime, were worked with the hands to separate them from each other, and besprinkled with a little water, to diminish the heat. This was repeated on the same day at 2 p.m. On the morning of the next day (the 4th of the whole preparation), the koji was ready and represented a greyish mass bound together by a white mycelium. We then weighed the whole mass of koji and took a sample for analysis. In this stage the koji must be transferred to a cold place otherwise the formation of spores

would soon set in and the whole mass would turn brown. Only for the purpose of producing a crop of spores for the next preparation of koji, some of the trays are kept in the warm part of the cellar until fructification has taken place.

In the manner just described we have carried out two quantitative trials in the miso works of Kagaya in Tōkyō (Yotsuya), one with rice and the other with barley. During the course of the preparation we measured the temperature of the grain in some important stages and found the following figures:

I. Rice.

Temperature of the steamed grain immediately after sowing the spores (October 16th, 1 p.m.): 28° C

Temperature on the trays:

		Tray No. 1.	No. 2.	No. 3.	No. 4.
October 17th, 8 a.m.	after spreading out	26° C.	26° C.	26° C.	26° C.
„ 18th, 6 a.m.	before stirring	41 „	40 „	40 „	42 „
	after stirring	37 „	37 „	38 „	38 „
„ 18th, 2 p.m.	before stirring	41 „	41 „	39 „	38 „
	after stirring	39 „	39 „	38 „	37 „

II. Barley.

Temperature of the steamed grain immediately after sowing the spores (October 25th, 6 p.m.): 35°C.

Temperature on the trays:

		Tray No. 1	No. 2	No. 3	No. 4
October 26th, 8 a.m.	after spreading the grain	26°C.	26°C.	26°C.	26°C.
„ 27th, 5 a.m.	before stirring	39 „	39 „	37 „	38 „
	after stirring	37 „	38 „	36 „	37 „
„ 27th, 2 p.m.	before stirring	39 „	40 „	38 „	37 „
	after stirring	38 „	38 „	36 „	36 „

As the cellars in which koji is made are not supplied with artificial heat, except when starting after having been disused for a time, and as the average temperature of the open air is in Tōkyō during October only 15.5 °C., we learn from the above figures that the heat generated during the growth of the

fungus by destruction of organic material is very considerable. Similar observations were also made by Atkinson who found that the difference between the temperature of the air outside and inside the cellar amounted to 23-25°C. in December and to 5-7°C. even in May, and that the rice on the trays was on the 3rd day of the manufacture about 13 °C. warmer than the air in the cellar.

The samples of steamed grain sown with spores were made air-dry in a water-stove, proper measures being taken to prevent by a sudden exposition to boiling heat any development of the fungus. In the koji we determined the total nitrogen, albuminoid nitrogen, ammonia, free acids, alcohol, and the solubility in small samples of the fresh substance, rubbing weighed portions with some pumice-stone in all cases in which the koji had to be extracted. The total solubility, ammonia, free acids, and alcohol were estimated in an aquous extract prepared by digesting finely crushed koji with cold water for 12 hours; the albuminoid nitrogen was determined in a precipitate thrown down in a decoction of fresh koji in in 40% alcohol to which a solution of cupric sulphate with some cupric acetate and afterwards sodium hydrate was added in such a quantity as to leave still a good trace of copper in solution. All other calculations were made from air-dry koji prepared by gradually transferring from a weighed portion small doses into a hot water stove to prevent any action of the ferments while drying. In the finely powdered air-dry material we determined the glucose and maltose in extracts prepared by repeatedly boiling weighed samples in alcohol of 80%. All other analytical methods were the same as mentioned in bulletin No. 2 with reference to the feeding stuffs. Difficulties only arose in the determination of the dry matter in the powdered air-dry koji, which continually diminished in weight, even after 40 hours of drying. This was due, as we proved by special trials, to a continual disengagement of acid vapours consisting probably of butyric acid. Hence we took as the final results the

weights found after 6 hours' drying, since finely powdered vegetable substances generally attain within that time a constant weight.

For the manufacture of koji we had taken of the steamed grain sown with spores a quantity just corresponding to the capacity of 4 trays, viz. in the case of rice 3457 grms. and of barley 3519.3 grms., wherefrom resulted 2673 grms. of rice koji and 2530 grms. of barley koji. The percentage composition of these materials was found to be as follows :

	Rice.		Barley.	
	Steamed grain and spores.	Koji.	Steamed grain and spores.	Koji.
Water	39.16	31.77	49.01	42.74
In the dry matter :				
Crude protein	7.81	8.97	10 79	12.92
Ether extract	2.23	7.21	1.19	4.74
Crude fibre	1.05	1.60	1.52	4.53
Starch, dextrin etc.[3]	87.97	70.97	84.63	64.62
Maltose	——	6.05	——	11.03
Glucose	trace	4.07	0.68	0.22
Ash	0.94	1.13	1.19	1.94
Total nitrogen	1.249	1.436	1.726	2.067
Albuminoid ,,	1.227	1.246	1.621	1.768
Non albuminoid ,,	0.022	0.190	0.105	0.299
Soluble in cold water	3.63	38.52	6.50	37.92
Ammonia	——	0.020	——	0.024
Volatile acids (as acetic)	——	0.079	——	0.003
Fixed acids (as lactic)	——	0.351	——	0.516
Alcohol	——	0	——	trace.

In the dry matter of koji we find accordingly a relative increase of all ingredients, except of carbohydrates, which appear to have been destroyed to some extent. The presence

[3] Calculated as the difference between 100 and the sum of the other components.

of noticeable quantities of maltose and glucose indicates that the ferment produced by the fungus commences to act already on the moist steamed grain, but the proportion of these sugars is far smaller than that observed in rice koji by Atkinson, who found no maltose but only glucose (dextrose) to the very high amount of 25.0 resp. 58.1 % of the dry matter. This difference between the latter's and our analyses is most likely due to the mode of extraction. While Atkinson appears to have digested the koji with cold water for a considerable time and to have then determined the sugar in the extract, thus allowing the ferment contained in the koji to display freely its amylolytic action on the gelatinized starch, we destroyed the ferment by the application of sudden heat before extraction. Our figures may therefore be justly regarded as representing the composition of koji as it actually is, whereas Atkinson's results illustrate the contents of koji extracts obtained not by dissolution in water alone, but materially altered by the action of the ferment on the soluble and insoluble ingredients of koji.

The alterations accomplished by the fungus during the manufacture of koji will be seen from the following table, which shows how much of each ingredient of koji is obtained from 100 parts of the dry matter of steamed seeded grain and its components :

	In 100 parts of dry matter of grain.	In the koji obtained therefrom.	More (+) or less (-) than in the grain.
A. Rice.			
Dry matter	100	86.71	-13.29
Crude protein	7.81	7.78	- 0.03
Ether extract	2.23	6.25	+ 4.02
Crude fibre	1.05	1.39	+ 0.34
Starch, dextrin, etc.	87.97	61.54	-26.43
Maltose	—	5.24	+ 5.24
Glucose	trace	3.53	+ 3.53
Ash	0.94	0.98	+ 0.04
Total nitrogen	1.249	1.245	-0.004
Albuminoid ,,	1.227	1.080	-0.147
Non-albuminoid nitrogen	0.022	0.165	+0.143
B. Barley.			
Dry matter	100	80.72	-19.28
Crude protein	10.79	10.43	- 0.36
Ether extract	1.19	3.81	+ 2.62
Crude fibre	1.52	3.66	+ 2.14
Starch, dextrin, etc.	84.63	52.17	—32.46
Maltose	—	8.90	+ 8.90
Glucose	0.68	0.18	— 0.50
Ash	1.19	1.57	+ 0.38
Total nitrogen	1.726	1.668	-0 058
Albuminoid nitrogen	1.621	1.427	-0.194
Non-albuminoid ,,	0.105	0.241	+0.136

The loss of material caused by the growth of the fungus amounts in the case of rice to 13.3, in that of barley to 19.3% of the total dry substance applied. As in these figures no account is taken of the small amount of water that enters the constitution of the starch and dextrin when they are converted into maltose and dextrose, the actual loss of carbon is pro-

bably a little greater. In the loss of organic matter the *albuminoids* have certainly a slight share, as in both kinds of grain about 12 % of their original quantity was decomposed into simpler nitrogenous bodies, among which exists a small proportion of ammonia. The total quantity of *nitrogen* applied appears not to have undergone any perceptible loss, as the slight decrease in the case of rice lies entirely within the limits of experimental errors and, in the case of barley, may have been caused by the mechanical treatment of the grain rather than by evaporation of ammonia or liberation of elementary nitrogen. The *crude fat* (ether extract) shows, as in all fermenting or decaying materials, a remarkable increase, due to a formation of organic acids and other compounds soluble in ether. Some *fibre*, too, is newly formed by the fungus for its cellular membranes, and the slight increase of *ash* is caused by the application of well water with which the koji is sometimes besprinkled during the manufacture.

The destruction concerns chiefly the *carbohydrates*, of which disappear from 100 parts of seeded dry rice applied, altogether 17.66%, of the barley 24.06%. Owing to the formation of a considerable quantity of dextrin, maltose, and glucose the solubility of the koji shows an increase as compared with the steamed grain. It must, of course, be kept in mind that the solubility of a substance which contains ferments is dependent on the temperature and quantity of water used for extraction and on the time during which the water is allowed to act on the substance. Hence absolutely accurate figures can hardly be obtained for the solubility of a specimen of koji.

With regard to the *active properties of koji* it appears to have been at once recognized by all those who have judiciously observed the process of *saké* brewing that this material is prepared and applied because of its saccharifying power, but the action of koji on starch and other carbohydrates was studied as early as in 1881, in which year R. W. Atkinson published elaborate researches on this subject. This author seems to have decisively ascertained that koji contains a

soluble ferment which acts on cane sugar, maltose, dextrins, and gelatinized starch, converting the three latter finally into dextrose, the former into inverted sugar. With reference to one point only the conclusions drawn by Atkinson do not appear fully justified. When examining whether maltose is one of the products of the action of koji extract on starch paste, he resorted to an indirect method, proceeding in the following way[4]:

In the koji extract as well as in the solution obtained after liquefaction of starch paste by the extract at 40° C. he determined the contents of the fluids in solid matter by the specific gravity (using the divisor 3.86), and also the specific rotatory power. Furthermore he determined, after saccharification, the reducing action upon cupric solution, and calculated from the amount of cuprous oxide, and from the weight of the starchy products (determined by the specific gravity) the weights of maltose and dextrin, assuming these to be the cnly products. "If no other substance is formed, the specific rotatory power of the solution calculated from the percentages of maltose and dextrin present will agree with the specific rotatory power of the solution actually observed. If they do agree the solution must contain the bodies assumed to be present, because if others were there, the specific rotatory powers would differ from one another."

Many of the assumptions involved in this method invite objection. The determination of the starchy products in solutions by the specific gravity is not reliable, as koji extracts (100 grms. of koji for 1 litre of water) contain up to 27% of nitrogenous bodies in their dry matter.—The koji extract itself alters upon being heated to 40°C; its rotatory power before and after the action on starch paste is consequently not the same, and ought to have been separately ascertained. —The specific rotatory power of dextrin assumed by Atkinson to be 216 for white light cannot be expressed by a constant

---

[4] L. c. p. 25.

figure, but is sure to alter in consequence of the action of ferments. Koji acts also on maltose; on a trial of the specific rotatory power after heating a solution of maltose and koji extract for 20 minutes to 45°C. the said author found a decrease of 13.1°, the maltose being converted into dextrose. Is it not probable, therefore, that, in the three experiments by which Atkinson claims to have proved maltose and dextrin to be the only products of starch, dextrose should have been formed at the same time?

Hence in spite of the wonderful coincidence of the specific rotatory powers, actually observed and calculated in the indirect way, by which Atkinson found the starchy products to consist,

in one experiment, of 56.27% of dextrin and 43.28% maltose,
in the second....... „ 28.46 „ „ „ 71.54 „ „
and in the third.... „ 30.00 „ „ „ 70.00 „ „
we cannot regard the presence of maltose among these products as decisively established. We therefore repeated some of the experiments made by that author and extended our researches over some other carbohydrates, proceeding in the following way:

Solutions of each carbohydrate were mixed with an extract made from koji by digesting 100 grms. of the latter with 500 c.c. of cold water for 12-16 hours and filtering. Usually for 200 c.c. of the solution of the carbohydrate 100 c.c. of the extract was applied, and the mixture was heated to 40-50°C. for 2-3 hours and then cooled. A small volume of koji extract was treated in just the same way as the mixture, care being taken that while heating no water should evaporate from the bottles. In all these fluids the optical rotation was determined at the same temperature (22-23°C.) with the help of a Wild's polaristrobometer by Hermann & Pfister, 200 millimeters' tubes and sodium light being used. The results of these observations were as follows:

I. Cane sugar. The mixture applied consisted of 150 c.c. of a cane sugar solution of about 10% and 100 c.c. of koji extract. The optical rotations found, were:

Solution of cane sugar	13.7°
Extract of koji, fresh..................	11.7°
„ „ „ , after heating	11.5°
Mixture, after heating	5.5°

If while heating the mixture of sugar solution and koji extract no inverson of the former had taken place, the rotation would have been 12.8°, while it actually had diminished to 5.5.° These figures enable us to calculate the proportion of cane sugar that had undergone inversion, in the following way:

The original cane sugar solution diluted with koji extract had a rotative power of 12.8° (=6.18 grms. of cane sugar in 100 c.c.), of which 8.2° were due to the sugar, while of the 5.5° observed after heating only 0.9° were caused by the cane sugar and its inverted products, the remaining 4.6° being due to the koji extract.

If the whole sugar had been inverted, the rotatory power of its products would have been—2.6.° Applying H. Landolt's[5] formula for the calculation of the cane sugar not inverted:

$$r = \tfrac{4}{7}\,(A-B)$$

in which r = the proportion (grms.) of cane sugar still present in 100 c.c., A = the rotation of the partly inverted sugar (+0.9°), B = the rotation after complete inversion(−2.6°), we obtain:

$$r = \tfrac{4}{7}\,(0.9- \;-2.6) = \tfrac{4}{7}\,3.5 = 2.0 \text{ grms.}$$

Of the 6.18 grms. of cane sugar 2.0 grms. had accordingly not been inverted. Hence 6.18−2.0=4.18 grms. e.g. nearly 70% of the whole sugar had undergone inversion under the influence of the soluble ferment of koji.

[5] Berichte der Königl. Preuss. Akademie der Wissenschaften zu Berlin 1887, 2. Halbbd., p. 980.

II. Milk sugar. The mixture consisted of 200 c.c. of a solution of milk sugar and 100 c.c. of koji extract, and was heated to 40-45° C. for 2½ hours. The following rotations were observed:

Solution of milk sugar	12.7°
Extract of koji, fresh	10.3°
„ „ „ after heating	9.9°
Mixture after heating..................	11.9°

Before the mixture was warmed, it had, according to the preceding figures, a rotatory power of 11.8°, which almost exactly coincides with the rotation actually observed after the koji had been allowed to act on the sugar. The experiment consequently shows, that milk sugar is not acted on by the ferment of koji.

III. Maltose. This experiment was carried out with the same proportions of sugar solution and koji extract as that with milk sugar. The optical rotations observed were, as follows:

Solution of maltose	13.0°
Extract of koji, fresh	10.3°
„ „ „ after heating	9.9°
Mixture after heating..................	8.4°

The original maltose solution contained 4.7 %, which amount was reduced by the dilution with koji extract to 3.134 %, equal to 8. 67° Wild. After the action of the ferment this rotation proved to be diminished to 5.1°. As a solution of maltose of 100° Wild yields, after the complete conversion into dextrose, only a rotation of 42.2°, the result of the experiment shows that a considerable proportion of maltose had been changed by the ferment of koji into dextrose. A calculation similar to that given in detail in the description of the experiment with cane sugar shows that the solution (koji extract deducted) contained after heating:

0.80 %	of maltose	=	2.5°	Wild and
2.46 „	„ dextrose	=	2.6°	„
3.26 %	„ sugars	=	5.1°	

More than 70 % of the original maltose had accordingly been converted by the ferment of koji into dextrose.

IV. Jnulin. The mixture applied consisted of 200 c.c. of a solution of inulin and 100 c.c. of koji extract. After warming it for 2½ hours to 40-45° C. the following rotations were observed :

Solution of inulin	— 2.8°
Extract of koji, fresh	+ 8.2°
„ „ „ heated...............	+ 7.7°
Mixture, after heating	+ 0.5°

Deducting the rotation caused by the koji extract, we find the solution of inulin to rotate before warming it with the ferment by—1.9°, and after the action of koji—2.1°. These results show that inulin is very probably not acted on by koji, the difference between the two rotations lying within the limits of experimental errors.

V. Starch. It might perhaps be possible to ascertain approximately the nature of the products obtained from starch by the action of the ferment of koji, if the polarimetric results were supplemented by determinations of the reducing powers of the solutions towards Fehling's solution before and after the ferment has acted on them and before and after the inversion of the solutions by strong acids. Reliable conclusions cannot, however, be drawn from researches of this kind, particularly because there will probably be found in the solution of starch after its alteration by the ferment: glucose, maltose, various kinds of dextrins, and unaltered starch of which the rotatory power of the two latter appears to be somewhat variable or at least, to have not been definitely ascertained, and moreover the dextrins do not admit of an accurate quantitative separation from maltose (by titration with Fehling's solution). Therefore we proceeded by the following way :

100 grms. of starch were gelatinized in 1500 c.c. of water,

allowed to cool to 40° C., and mixed with 500 c.c. of an extract made from 25 grms. of rice koji likewise warmed to 40° C. The mixture was kept at this temperature for 25 minutes, then rapidly heated to boiling, evaporated to a syrup, and extracted with alcohol, to separate the unaltered starch and the dextrins which are insoluble in strong alcohol. The alcoholic extract was again evaporated to a very small volume, once more taken up with alcohol of 95%, the extract freed from the alcohol by evaporation dissolved in water and decolorized by well purified animal charcoal. It was finally evaporated to a small volume and allowed to stand for several weeks, but no crystallization took place. The total quantity of dry matter thus obtained amounted to about 30 grms. We dissolved about 10 grms. of it in 100 c.c. of water and determined the rotatory power before and after inversion with hydrochloric acid, and also the reducing power towards Fehling's solution, paying due regard to Soxhlet's suggestions. The results were, as follows :—

	Before inversion.	After inversion.
Reducing power, dextrose............	4.04%	7.46%
Rotatory power, °Wild	20.9°	8.4°

Assuming the reducing power before inversion to be due only to maltose, we find that that it would correspond after inversion only to 6.97% dextrose, whereas the actual observation yielded 7.46%, e. g. a surplus of 0.49% dextrose. This result indicates that in the original syrup a substance was present, having less effect on cupric solution than maltose. Hence it is probable that the syrup still contained some dextrin, and, indeed, if we assume the above amount of 0.49% dextrose to have been formed from dextrin by inversion, the original solution would contain.

		Before inversion.	After inversion.
6.62% maltose	having a rotatory power of	18.30°	7.9°
0.45 dextrin		1.8°	
		20.1°	
Actually observed.....................		20.9	8.8°

The coincidence between the rotatory powers actually observed and calculated on the above assumption indeed renders it very likely that the syrup contained among the reducing substances only maltose and some dextrin. As the rotatory powers found before and after inversion differed by the same amount (0.8—0.9°) from the rotations calculated, it appears that a small amount of an optically active substance other than maltose and dextrin was present, which was not altered by the inverting reagent. Glucose was not present in the syrup, but appears to have been separated from it by the extraction with strong alcohol.

The experiment just described though pointing with great probability to the presence of maltose among the products obtainable from gelatinized starch under influence of the ferment of koji, does not yield a proof as decisive as desirable, probably because the extract of koji applied contained some substances other than maltose that could not be removed from the syrup by our method of purification. We therefore tried the following way: 500 grms. of koji was digested for 24 hours in glycerin, the extract precipitated with absolute alcohol containing some ether, the flocculent greyish precipitate dissolved in a little water and again thrown down by absolute alcohol. The white mass thus obtained, included much of the ferment of koji, as after dissolution in water it exhibited a strong saccharifying power when allowed to act on gelatinized starch. Thereupon 250 grms. of starch were converted into paste with about 4 litres of water and, after cooling to 40-45° C. the gelatinous mass was well mixed with the aquous solution of the ferment likewise gradually warmed to that temperature. The mixture was kept in warm water at 40-45° C. for three hours and then allowed to stand at ordinary temperature until the next day. It was then evaporated to a syrup and mixed while still warm with a ninefold volume of absolute alcohol, filtered and still repeatedly extracted with warm alcohol of the same strength. The extracts were united, freed from the alcohol by distillation, evapo-

rated to a syrup and again extracted with alcohol of 95%. This was repeated once more, the syrup dissolved in water, digested with purified animal charcoal, and evaporated to a small volume, which, mixed with some strong alcohol, upon standing several weeks solidified to a completely white crystalline mass. Unfortunately the quantity of crystalline sugar thus obtained was too small (about 50 grms.) to admit recrystallization. We therefore again determined before and after inversion the rotatory and reducing powers in a solution containing about 7.5 grms of it. The results were as follows:—

	Before inversion.	After inversion.
Reducing power, dextrose	5.008%	7.318%
Rotatory power, °Wild...	17.1°	8.0°

Dextrin was entirely absent from the crystalline mass, as the latter completely dissolved in hot alcohol of 95% when repeatedly treated with it. The sugars could consequently only consist of glucose or maltose or a mixture of both, and the above results of the optical examination along with the reducing powers, decidedly prove that the solution contained:

		Before inversion.	After inversion.
Maltose 5.214 %	having a rotatory power of...	15.2°	7.7°
Dextrose 1.827 ,,		1.9°	
Rotatory power, actually observed	....	16.9°	8.0°

The results found by titration with Fehling's solution and the rotatory powers so closely coincide that there can be no doubt about their meaning: *The ferment of koji produces maltose and dextrose when allowed to act on gelatinized starch.*

Some of the sugars were treated in an aquous solution with hydrochloride of phenylhydrazin and sodium acetate in the quantities suggested E. Fischer. Upon warming the mixture on a water bath we obtained a yellow crystalline precipitate consisting of fine needles, which partly dissolved easily in warm water and separated again on cooling, while another

portion of them was less soluble in water, but soluble in boiling alcohol. This deportment also coincides with our above result, according to which the sugars consist of maltose and glucose.

As the ferment of koji also converts maltose into dextrose, a protracted action of a large amount of the ferment on comparatively small proportions of starch will probably result in a complete conversion of the maltose formed in the beginning, and dextrose may be the final product.

Reviewing the results arrived at by the preceding researches we see that *the ferment of koji has strong diastatic properties : It converts cane sugar with great ease into dextrose and lævulose, maltose into dextrose, and gelatinized starch into dextrin, maltose and dextrose, whereas it does not act on milk sugar or inulin.* Now it is known that another fungus, likewise applied in fermenting industries, viz. beer yeast, also contains a soluble ferment which vigorously inverts cane sugar and resembles in this respect and also in regard to its destruction by a comparatively low heat the ferment of koji[6]. Other carbohydrates appear, however, not to be altered by the yeast ferment; at least M. J. Kjeldahl[7] reports that he observed no action on dextrin and maltose, and Kiliani[8] none on inulin.

Although we desired to systematically compare these two ferments we unfortunately could not procure absolutely pure-bred bottom yeast, obtainable at present only in Europe but had to take our material from a well conducted brewery at Yokohama. Microscopic examinations, however, showed that only minute quantities of cells of other yeast were present in it. About 300 grms. of this yeast were triturated with granular pieces of glass, extracted with water and filtered through asbestos. The extract amounted to about 500 c c. and was slightly opalescent. It served, immediately after

[6] Atkinson (l. c. p. 33) found the koji extracts become completely inert at a temperature between 60° and 70° C.
[7] Biedermann's Centralblatt für Agriculturchemie, vol. 11, 1882, p. 791.
[8] Chem. Centralblatt, 1882, p. 414.

preparation, for researches on its effect on several carbohydrates, which were carried out under the same conditions and at the same time as the above experiments with extracts of koji. The following trials were made :

I. Cane sugar. 100 c.c. of sugar solution and 50 c.c. of yeast extract were digested at a temperature of 40-45°C for 3 hours in closed bottles and examined with the polarimeter after cooling to 23°C. The rotations, degrees Wild, were found to be, as follows :

Yeast extract, fresh..................	+ 1.6°
,, ,, , after heating	+ 1.0°.
Cane sugar solution..................	+12 9°
Mixture, after heating	— 2.4°

The result at once distinctly proves that the yeast extrac effected the inversion of a considerable proportion of cane sugar. If the ferment applied had left the sugar unaltered, the rotation of the mixture would have amounted after heating to 8.9°, while it actually diminished to—2.4°. Applying Landolt's formula we find that the whole cane sugar had undergone inversion by the ferment.

II. Milk sugar. In this experiment and in all the following the same kind and proportion of yeast extract was used as in the experiment on cane sugar just discribed and also applied in the corresponding trials on the effect of koji extract. The rotations were, as follows :—

Milk sugar alone	12.7°
Mixture, after heating	9.0°

If the yeast extract had not exerted any effect on the milk sugar, the rotation, after heating the mixture, would have been 8.8°, whereas 9.0° was actually observed. This slight difference lies within the ordinary limits of experimental errors, and the experiment shows, that milk sugar is not acted on by yeast extract.

III. Maltose. The optical rotations observed were, as follows:

Maltose alone..................................13.0°
Mixture, after heating........................ 9.2°

Assuming that no alteration of the maltose had taken place during its digestion with yeast extract, the rotatory power of the mixture would have been 9.0°. As the result of the actual observation was very nearly the same, we may conclude that maltose is not affected by yeast extract. Another experiment made with invertin precipitated from the aquous extract of triturated yeast with strong alcohol and redissolved in water gave the same result, viz., :

Rotation of the maltose solution alone.........33.5°.
„ of the yeast ferment, after heating... 4.0°.
„ of the mixture, after heating.........25.0°.

As the mixture consisted of 50 c.c. of maltose solution and 20 c.c. of dissolved yeast ferment, its rotation must have originally been 25.1°. After heating 25.0° were observed, whence the yeast ferment had not influenced the maltose.

IV. Inulin was also not affected by solutions of the yeast ferment. The rotations observed were the following:

50 c.c. of inulin solution, fresh..............−2.8°.
25 c.c. of yeast extract, heated..............+1.0°.
mixture, after heating.......................−1.5°.

Calculated from the rotations of the solutions applied, the mixture should have shown—1.5°, which happens just to coincide with the rotation observed.

V. Starch. Several experiments were made with starch, previously extracted repeatedly with strong alcohol to remove

all traces of reducing sugars, gelatinized and mixed with solutions of invertin that had been thrown down from yeast extract by strong alcohol, washed, and redissolved in water[9]. Neither the gelatinized starch nor invertin reduced alkaline cupric solutions. The mixtures were kept for several hours at 45°C and then tested with Fehling's solution. Not a trace of reducing sugar had been formed. A test with phenylhydrazin hydrochloride and sodium acetate also gave a negative result. Hence we may safely conclude that starch is not acted on by the soluble ferment of yeast.

Comparing now, by the light of the preceding researches, the effects of the two ferments,—yeast and koji—on the various carbohydrates, we find that neither of them acts on inulin or milk sugar, but that they strongly invert cane sugar, and also that the invertin of yeast does not affect gelatinized starch or maltose, while the ferment of koji hydrates both, converting starch into dextrins, maltose, and dextrose, and maltose into dextrose. There is accordingly an essential difference between the two ferments, that of koji having stronger hydrating properties than that of yeast. In order to discriminate between the two and at the same time give expression to their resemblance in respect to their identical action on cane sugar, we may be allowed to give to the soluble ferment of koji the name "*invertase.*"

When improperly stored in a damp room without sufficient ventilation, koji is liable to turn sour, whereby the efficacy of the invertase is either diminished or entirely suspended. Some interest must accordingly be attached to a determination of the quantity of acid in the presence of which the ferment becomes ineffective. We investigated the subject, choosing that acid which is chiefly formed under natural conditions in moist starchy materials, viz. *lactic acid.*

[9] This solution of the ferment rapidly inverted cane sugar.

Solutions of cane sugar, which, as we have seen, are so speedily affected by invertase, were mixed with gradually increasing quantities of lactic acid, filled up in each trial to a uniform volume, mixed with the same quantity of koji extract and kept in warm water at 40-45°C for 2 hours. For each trial 100 c.c. of a solution containing 10 grms. of cane sugar, 50 c.c. of a standardized solution of lactic acid and 50 c.c. of freshly prepared koji extract were used. In one trial the solution of lactic acid was replaced by an equal volume of water. After heating, all the mixtures were cooled to the same temperature and then examined in the polaristrobometer. The rotations observed, were, as follows:

Lactic acid, % of the mixtures......	0	0.25	0.50	0.75	1.0
Optical rotation.........	6.6°	8.2°	8.5°	8.7°	8.7°

Four other mixtures of the same solutions, containing 1.25, 1.5, 2.0 resp. 2.5% of lactic acid also showed, after heating, 8.7°. Here we see that the smallest quantity of acid applied (0.25%) already interfered with the action of the invertase and that 0.75% probably entirely suspended the inversion.

As in this experiment the solution of the ferment applied was not very effective owing to the too short digestion of the koji with water, we made a second series of trials heating the mixtures to 40-45° for 2½ hours and using the same proportions of koji extract and solutions of cane sugar and lactic acid as before, viz. 100 c.c. of a solution of cane sugar, 50 c.c. of lactic acid, and 50 c.c. of koji extract. Along with these mixtures we heated also 1) 50 c.c. of koji extract diluted with 150 c.c. of water, 2) 100 c.c. of cane sugar + 50 c.c. of koji extract + 50 c.c. of water, 3) 100 c.c. of cane sugar + 100 c.c. of a solution containing 4 grms. of lactic acid, and4) 50 c.c. of koji extract + 150 c.c. of a solution containing 2 grms. of lactic acid. After heating, the optical rotations were found to be, as follows:

	Contents of lactic acid, %	Optical rotation, °Wild.	Cane sugar inverted while heating.	Relative effect of the ferment on cane sugar 10.
1) Koji alone	—	2.05	—	—
2) „ +acid	0.5	1.55	—	—
3) Cane sugar alone	0	6.85	—	—
4) „ „ +acid	2 0	6.8	0	—
5) „ „ +koji	0	5.5	1.94	100
6) Cane sugar + koji +acid.	0.05	4.6	2.46	127
7) „	0.10	6.3	1.485	77
8) „	0.20	7.8	0.63	32
9) „	0.30	7.9	0.56	29
10) „	0.40	8.2	0.40	21
11) „	0.50	8.2	0.40	21
12) „	0.60	8.3	0.34	18
13) „	0.60	8.4	0.29	15
14) „	0.80	8.5	0.23	12
15) Lactic acid	5.00	0	—	—

As the lactic acid alone was found to be optically inactive and as it also did not invert any trace of cane sugar (trial 3 and 4), we must conclude from the gradual diminution of the inversion observed in trials 7-14 that the lactic acid, when present in quantities of 0.1 % and more, gradually diminishes the inverting power of the invertase. In trial 6, the proportion of 0.05 % of lactic acid makes an exception, it favours the action of the ferment, a fact which need cause no surprise, as a similar amylolytic ferment, the diastase of malt exhibits according to Kjeldahl[11] the same deportment, being almost inactive in neutral solutions but displaying the strongest action in slightly acid fluids and suspending entirely its saccharifying power in the presence of large proportions of acid.

The figures (in the last column of the above table) showing the relative effect of invertase on acid cane sugar solutions

---

[10] Found by setting the quantity of inverted sugar in trial 5 as equal to 100 and calculating the corresponding amounts on this basis.

[11] M. Mærcker, Handbuch der Spiritusfabrikation, 1880, p. 37.

still require correction, because, according to trials 1 and 2, our koji extract appears to be altered when warmed with lactic acid. To eliminate this action from the results it would have been necessary to make parallel trials with koji extract and gradually increasing quantities of acid. As, however, only one such trial (No 2) was made, we may simply assume the diminution of the rotative power observed to be 0.5° in the presence of 0.5% of lactic acid, to have been the same in all other trials. On that supposition we obtain the following results, which approach nearer the truth than those in the above table:

Trial	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Rotation	5.5°	5.1°	6.8°	8.3°	8.4°	8.7°	8.7°	8.8°	8.9	9.0
Relative effect.	100	112	62	18	15	6	6	3	0—3	

Here we see that a proportion of about 0.05% of lactic acid (trial 6) had the best effect, and that when the amount of acid is increased to 0.1% and more, the inverting power of koji extract is rapidly diminished, until at a content of 0.6%, and more (trial 11-13), it is suspended.

In an additional trial in which a mixture of cane sugar and koji extract containing 2% of lactic acid, had been heated for 2½ hours to 40-45°C., we neutralized after cooling to a slightly acid reaction and warmed again, but the invertase proved not to have recovered its efficacy by the neutralization.

In the manufacture of *shoyu* and *miso* koji is always applied, along with a very large quantity of common salt; the former contains 150-160 grms. of sodium chloride in one litre,

the latter 6-12% by weight Ferments appear, however, to be rather sensible to the presence of neutral soluble salts, and to be weakened by them. An addition of sodium chloride to a mixture of malt extract and gelatinized starch diminished according to O Nasse[12] the amount of sugar so much that, while under equal conditions without any addition of sodium chloride 100 parts of sugar were formed from the starch, only 53 parts were obtained in the presence of 4% of this salt. In order to ascertain whether and how far the koji ferment is weakened by an addition of common salt to its solutions we carried out the following experiments:

I. Solutions containing 2% of air-dry starch prepared according to the proposal of Lintner jun., 200 c.c. each, were mixed with 45 c.c. of an extract made with 500 c.c. of water from 25 grms of *barley* koji, and various quantities of sodium chloride were added. These mixtures were kept in water of 40°C. for 2 hours, and then the quantities of reducing sugars, calcutated as dextrose were determined by titration with Fehling's solutions. The results, after deduction of the contents of the original koji extract, were, as follows:

Sodium chloride in % of the mixture.	Reducing sugars as dextrose.	Relative proportions.
0	0.271%	100
2.0	0.091 ,,	33.6
9.3	0.055 ,,	20.3
17.6	traces.	

The koji applied in this trial was a little old and not very effective.

II. Another series of experiments was made with rice koji, the same proportion of starch solution and koji extract as above being used. The quantities of reducing sugars produced from the starch and calculated as dextrose were found to be the following:

[12] M. Maercker Handbuch d. Spiritusfabrikation. 1880, S53.

Sodium chloride in % of the mixture	Reducing sugars as dextrose	Relative proportions
0	0.612%	100
2	0.357 ,,	58.3
6	0.159 ,,	26.0
12	0.024 ,,	4.0
20	0.010 ,,	1.6

III. A third series with another sort of rice koji, carried out in the same way, gave the following results:

Sodium chloride in % of the mixture	Reducing sugars as dextrose.	Relative proportions.
0	0.444%	100
2	0.223 ,,	50.2
4	0.155 ,,	34.9
10	0.054 ,,	12.2
15	0.040 ,,	9 0
20	0.033 ,,	7.7

Slight admixtures (2%) of common salt to solutions of carbohydrates interfere much with the effect of the koji ferment, whereas the saccharifying power is not entirely checked even by a content of salt as large as 15-20%.

Researches on the Manufacture and Composition of "Miso."

CARRIED OUT IN CONJUNCTION WITH

M. Nagaoka and Y. Kurashima

BY

Dr. O. Kellner.

Miso, e.g. a food prepared from a mixture of soy beans, rice or barley, common salt, and water, by slow fermentation, seems to have been known in Japan since remote times. Its manufacture, like so many other useful processes, appears to have been taught to the Japanese by Chinese or Koreans. At least the *Sandai jitsu roku*, one of the oldest Japanese records, tells us, that a Chinese priest named *Jingo* transmitted more than 1000 years ago a small quantity of miso to the then Emperor of Japan, and the name "*Korei shiwo*" sometimes, though not frequently used instead of the word "miso," points to its introduction from Korea, where indeed, as well as in China, miso is still a favorite food.

In Japan miso is very widely consumed, especially by the lower classes who enjoy it as a sort of food adjunct to the vegetables of which their diet chiefly consists. Although it is eaten throughout the whole country, it seems to be specially favoured in the north-eastern provinces. Statistics on its consumption do not exist at present and may also be difficult to compile, as in the country it is made by the families themselves, and only in large communities are special miso works established. Assuming, however, 10 *momme* (37.5 grms.) to be

the lowest quantity daily consumed per head, and 20 millions out of the 39 of the whole population to eat miso every day, a yearly amount of nearly 30 million kilograms of miso is arrived at, for the preparation of which more than half the total yearly produce of soy beans (2.3 million *koku* in 1883) is needed. Although these figures are certainly too low, they surely indicate the importance of this food in the nutrition of the Japanese people.

I. Raw Material and Preparation of Miso.

1. *Soy beans.*

Among the raw materials, soy beans occupy the first rank as well with regard to quantity as to the contents of the probuct in nutritious matters. Of the numerous varieties of soy beans cultivated in Japan preference is given to one known as miso mame (miso bean) which yields yellowish white grains somewhat smaller than the blue and brown kinds. It ripens a little late, but yields a good crop, and is cultivated, like all other varieties, as a second crop after wheat or barley. Corresponding to its use the cultivation of the soy bean is more extended in the northern part of the main island than in the south. The best beans for the manufacture of miso are said to come from the neighbourhood of Mount Tsukuba in Ibaraki prefecture, and good sorts are also raised in the province of Joshiu, while the plain of Musashi does not produce any particular good kind. In Miyagi prefecture large-grained soy beans are cultivated which are perferred for special varieties of miso (Shiro and Sendai miso), because they confer a better appearance on the product.

Analyses made in our laboratory by Mr. *J. Sawano*, of soy beans which were reported to be specially suited for the manufacture of shoyu, but which had likewise the properties of good miso beans, gave the following results :

	No. 1.	No. 2.	No. 3.
Water	11.92%	11.90%	12.87%
In the dry matter:			
Crude protein	42.59 ,,	42.79 ,,	43.18 ,,
Fat	20.46 ,,	20.56 ,,	20.78 ,,
Crude fibre	4.53 ,,	4.46 ,,	4.05 ,,
Nitrogenfree extract	28.82 ,,	28.50 ,,	28.14 ,,
Ash	4.19 ,,	3.69 ,,	3.85 ,,
Weight of 1000 grains in grms.	171.6	148.0	107.8

The beans which serve for the manufacture are first sorted, all grains that are broken or imperfectly developed are picked out and the rest sifted through several sieves to separate too small or too large grains. Only uniformly sized well formed beans are taken. They are then washed and allowed to steep in clean water usually for one night, after which they are steamed in a wooden tub furnished with a false bottom, covered with cloth and fixed upon an iron boiler, in which the steam is generated. The steaming is regarded as the most critical part of the process and requires the utmost care, because upon it the quality and colour of the product principally depend. It is continued for a long time, 20-48 usually 36 hours; however not continuously, but in periods, so that for example within 48 hours the beans are exposed 3 times to full steam always for 8-10 hours, while between these three periods of steaming the fire is taken away from under the boiler. In households the beans are simply boiled and are ready for the further treatment within a shorter time, 12-20 hours. After steaming or boiling, the condensed water is allowed to drain off from the beans, and the latter are transferred into a capacious vat in which they are allowed to cool to a temperature varying between the wide range of 20-90°C. according to the sort of miso to be prepared.

2. *Koji from rice or barley.*

The preparation of koji, its composition and properties have already been described in No 5 of the Bulletins of this College,

to which reference may be made. Both rice and barley koji are made use of.

3. *Common salt.*

Salt is procured in Japan exclusively from sea water, which is allowed to dry on sandy beds near the shore. The superficial sandy layer of the beds is extracted with a small quantity of sea water, and the concentrated solution is then evaporated nearly to dryness in iron pans over a fire, whereupon it is allowed to cool. The crystals of common salt which then deposit, are collected into baskets, the brine containing chiefly magnesium salts is allowed to drain off, and the salt is then further dried in the sun. The product thus obtained is, of course, still very impure. Analyses by O. Korschelt and M. Hida[1] and by K. Kogajima[2] of several specimens of salt from various districts in Japan, gave the following results :

	Ajino, Bizen.		Ako, Harima.			Mitajiri, Suwo.	Giotoku, Shimosa.
	a	*b*	*a*	*b*	*c*		
Water	3.32	1.70	1.36	1.65	4.42	2.28	4.52
Sodium chloride	84.80	91.55	91.01	92.11	92.34	87.75	89.37
Potassium chloride	2.38	1.66	1.35	1.76	1.13	1.57	1.84
Magnesium chloride	3.83	1.86	3.30	1.59	0.40	2.74	1.62
Calcium chloride	1.82	1.74	1.38	0.87	0.82	2.04	1.22
Magnesium sulphate	3.39	1.15	1.56	2.02	0.88	3.56	1.35
Insoluble matter	0.05	0.07	0.04	——	0.01	0.06	0.08

The 3 raw materials described are mixed, as already stated, at very different temperatures of the steamed beans, and it seems, that the course of the subsequent fermentation and the keeping qualities of the product are principally determined by this circumstance. For example, in the manufacture of shiro miso (white miso) the beans are still so hot when they are mixed with koji and salt, that the workmen, who perform the operation by treading, have to wrap their feet in straw to protect them from scalding. This kind of miso ripens very early and is ready for

[1] Chishitsu Chosajo (Meiji 16th) No. 2, p. 286 (second report of the Imperial Geological Survey, in the Japanese language).

[2] Nihon Shokuji, Meiji 18th, p. 180 (in the Japanese language).

consumption after 4 days. If the beans are, however, allowed to cool down to the temperature of the air, as is the case in the preparation of Sendai miso, the fermentation proceeds very slowly and the miso is not ripe until after 8—15 months. The common salt is usually dissolved in a very little hot water, and when cold, is poured into the mixing vat partly during the mixing, partly afterwards. The treading is continued until all the grains are freed from the hulls, and the cotyledones of the beans are separated. The mixture is finally transferred into large wooden tanks covered with straw mats or wooden lids upon which some heavy stones are laid. There it is left till maturity, which is judged exclusively by the taste.

On the preparation of the raw materials some data will be found later on in the description of the principal varieties of miso (part III).

II. The Chemical Processes during the Ripening of Miso.

As there exist no investigations on this subject, and as even the analyses hitherto made of miso are too incomplete to admit of reliable conclusions on the alterations of the materials mixed and stored for ripening, Mr. *Y. Kurashima* who to our great regret died this year, has tried in 1887 to throw some light on these processes by analyzing specimens of *inaka miso* (country miso) taken from a large fermenting vat at different periods.

The factory, which very kindly granted us the material for the experiments, is in the province of Shimōsa ; and the samples, each weighing several kilograms were sent to the laboratory in well closed small barrels specially made for the purpose. The raw materials applied in the present case, were a variety of soy beans called *aka saya*, grown in the neighbourhood of the factory, a rather inferior sort of barley of an early variety known as *roku kaku wase* (six-edged variety), and a medium quality of salt, prepared at Ako in tho province of Harima.

The beans and the barley, the latter already hulled had the following composition :

	Soy beans %	Barley %
Water	14.27	14.36
In the dry matter :		
Crude protein	43.98	9.83
Fat	18.71	1.65
Crude fibre	4.47	1.81
Starch	17.70	81.17
Dextrin, Glucose, etc	11.39	3.66
Ash	3.75	1.88
Total nitrogen	7.037	1.572
Albuminoid nitrogen	6.501	1.507

After all the barley had been converted into koji in the manners described in Bulletin No 5 the beans were steamed three times for 10 hours each at intervals of 6 hours, during which they were kept in the hot steaming tub. In the meantime the salt was dissolved in cold water (1 litre of water for every 0.3 litre of salt) and mixed with the barley koji in a shallow vat. When the beans had cooled to the temperature of the air after steaming, they were gradually put in small portions into the mixing vat containing the koji, and mixed with the latter by treading. The well mixed materials were transferred into a large vat, 5 feet deep and 7 feet in diameter and covered with a wooden lid charged with heavy stones.

There had been applied :

Barley	8.77 koku	=1230 kilogrms.
Beans	15.40 ,,	=2000 ,,
Salt	6.16 ,,	

Water about 600 sho = 900 litres.

Specimens for the analysis were taken from the centre of the vat on the following days :

1) 50 days after mixing (on March 1st).
2) 85 ,, ,, ,, (on April 5th).
3) 120 ,, ,, ,, (on May 10th).
4) 150 ,, ,, ,, (on June 10th).

The quantitative determinations[3], which were all made with the fresh substance after mixing and grinding it in a mortar to a fine pulp, gave the following results for the percentage composition :

A. FRESH SUBSTANCE.

	1.	2.	3.	4.
Water	49.03	50.82	52.89	53.51
Organic matter	37.73	35.31	32.87	3078.
Ash	13.24	13.87	14.24	15.62
Soluble in cold water	33.40	31.64	29.24	28.47
Insoluble	17.57	17.54	17.87	18.02
Crude protein	12.18	12.55	13.65	14.31
Ether extract	6.34	6.76	7.29	7.87
Crude fibre	2.31	2.43	2.55	2.68
Nitrogenfree extract	16.90	13.57	9.38	6.02
Ash free from sodium chloride	2.32	2.39	2.06	2.70
Sodium chloride	10.92	11.48	12.18	12.91
Starch, dextrin, etc	8.47	8.11	5.46	3.41
Glucose	8.36	7.51	4.81	4.38
Total nitrogen	1.949	2.008	2.184	2.290
Albuminoid nitrogen	1.548	1.485	1.419	1.370
Non-albuminoid nitrogen	0.401	0.523	0.765	0.920

[3] The analytical methods applied were the same as those described in No 5 of the Bulletins of this College, p. 12.

B. DRY MATTER.

	1.	2.	3.	4.
Organic matter	74.03	71.80	69.77	66.40
Ash	25.97	28.20	30.23	33.60
Soluble in cold water	65.53	64.34	62.07	61.23
Insoluble " " "	34.47	35.66	37.93	38.77
Crude protein	23.90	25.52	28.97	30.79
Ether extract	12.43	13.75	15.48	16.93
Crude fibre	4.54	4.94	5.41	5.71
Nitrogenfree extract	33.16	27.59	19.91	12.97
Ash, excl. sodium chloride	4.14	4.85	4.38	5.84
Sodium chloride	21.43	23.35	25.85	27.76
Starch, dextrin, etc	16.62	16.49	11.58	7.33
Glucose	16.40	15.28	10.21	9.43
Total nitrogen	3.824	4.083	4.635	4.925
Albuminoid nitrogen	3.037	3.019	3.012	2.947
Non-albuminoid nitrogen	0.787	1.064	1.623	1.978
" " " in % of total nitrogen	20.58	26.06	35.02	40.16

Throughout the time covered by our researches there continued a steady slow fermentation connected with essential alterations of the composition of the ripening miso. The single ingredients are affected by the process in the following way:

a) The *nitrogenous substances*, which figurate under their collective name "crude protein" undergo a slow decomposition which particularly concerns the *albuminoids*. While the proportion of *non-albuminoid bodies* among the total nitrogenous substances of the soy beans and even in the koji of barley is not considerable, amounting as to their content in nitrogen only to 9.24 resp. 14.47% of the total nitrogen present, we learn from

the above table that it increases in the course of the fermentation to 40%. The whole quantity of albuminoids which thus disappears, is really broken up into simpler compounds of the character of amides, organic ammoniacal and xanthin bodies; very minute proportions of them seem to be converted into peptons, and a slight quantity of the nitrogenous bodies is decomposed so far as to yield votatile ammoniacal substances, which existed in the dry matter of the 4th sample only to the amount of 0.25% nitrogen.

b) As to the *ether extract* (crude fat), we notice a gradual increase, which does not, of course, consist of fat, but is merely the result of the formation of free lactic, butyric, and other organic acids and other not well known substances which dissolve along with the fat in the ether, a fact already frequently observed to take place in all kinds of fermenting matters.

c) The *carbohydrates* are likewise very materially affected by the fermentation. The invertase of the koji continues to act, after mixing, upon the starch not only of the barley but also upon that of the soy beans, in spite of the presence of a considerable proportion of sodium chloride[1]; the gelatinized starch and the dextrin undergo saccharification continually, only the trifling amount of 7.33% is finally left of them in the miso, whereas the barley koji and beans contain 73.87 resp. 29.09%. The glucose formed from them seems, like the albuminoids, to serve for the nutrition of the fungus, the majority of it is used up in the respiration of the living cells, as carbon dioxide copiously escapes during the fermentation, causing the dough to swell up, especially in the first months after mixing the raw materials. At the same time a not inconsiderable quantity of *alcohol* is generated which fact is not surprising, since the same fungus is employed for the saccharification and production of alcohol in the manufacture of saké (rice wine) and shochiu (alcohol), though in the analyses of miso hitherto published alcohol is not quoted as a regular constituent. A determination of it was only made in the 3rd sample,

---

[1] See No 5, p. 32 of the Bulletins of this College.

which contained in the fresh state 3.63%.[5] It is furthermore very likely that some of the carbohydrates are destroyed by processes identical with or resembling those which yield marsh gas from organic substances, if the latter are kept under water in absence or deficiency of oxygen. The conditions to which the raw materials are subjected in miso manufacture are not very different from the latter. Another portion of the carbohydrates along with the albuminoids probably furnishes the material for the formation of the cellular membranes of the mycelium and for the organic acids, of which we found to be present in the 3rd sample 0.037% of volatile (calculated as acetic) and 0.411% of fixed (calculated as lactic) acids[5] in the free state.

d) The *crude fibre* slightly increases in the dry matter of the fermenting mass, probably in consequence of the destruction of the other organic components. A portion of it is likely to be reformed by the fungus as membrane of new cells.

e) The relative increase of the *ash* including *common salt* shown by the tables was to be anticipated on account of the destruction of organic matter.

f) *The solubility* of the fermenting dough gradually diminishes, because the saccharification and dissolution of albuminoids do not keep pace with the destruction and volatilisation of the organic substance, the latter processes being obviously accomplished to a larger extent than the former.

g) The mixture becomes in the course of the fermentation relatively richer in *water*, which is also a consequence of the gradual loss of dry organic matter. The evaporation of water from the vat, though restricted by the lid, is certainly not entirely prevented and does not counterbalance or outweigh the loss of solid matter.

Having taken into account in the preceding chiefly the alterations which concern the percentage composition of miso

---

[5] Further determinations of alcohol and free acids will be found at a later part of this paper in the record of analyses of different varieties of miso. It is probable that also small quantities of acetone are produced during the fermentation.

in different stages of maturity, we may now enter into a discussion of the *changes in the quantities of the various ingredients.* Unfortunately we have not been able to analyze the fresh mixture of the beans and barley koji, but as the proportions of beans and hulled barley applied had been determined with tolerable accuracy, we are in a position to compare the quantities of the single ingredients contained in the raw materials with those obtained in the finished product. In the composition of the dry matter applied, excluding the common salt, the soy beans participate with 61.98% and the hulled barley used for the preparation of koji with 38.02.%., both together with a content of 31.00% of crude protein. As other facts, to be explained hereafter, show, that no essential loss of nitrogen takes place during the fermentation, we will calculate from the composition of the finished miso how much of the other organic ingredients correspond to 31.00 parts of crude protein and will thus obtain the components left in the miso from 100 parts of the dry matter of the raw materials after complete fermentation. In this way we arrive at the following figures:—

	Total dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	Nitrogen-free extract[6]
Soy beans	61.98	59.66	27.26	11.60	2.77	18.03
Barley	38.02	37.31	3.74	0.63	0.69	32.25
Total	100	96.97	31.00	12.23	3.46	50.28
In the miso, obtained therefrom	—	66.40	31.00	17.04	5.75	12.61
Increase(+) or decrease(—)		—30.57	—	+4.81	+2.29	—37.67
do. percent of each single ingredient		— 31.7	—	+39.3	+66.2	—74.9

In consequence of the conversion of the barley into koji and the subsequent fermentation of the steamed beans and koji, nearly ⅓ of the total organic substance is lost. Almost ¾ of

[6] Calculated as the difference between the organic matter and the sum of all other ingredients.

the nitrogen-free extract disappear, if we calculate them, as was done in the above, as the difference between the sum of the other ingredients and the total organic matter. Direct determinations, however, prove that the destruction of the carbohydrates takes place in fact to a little less extent *viz.* amounting only to 33.41 parts out of 50.28 parts applied e.g. to 66.4%. This apparent discrepancy is merely the result of the customary calculation of the so-called "crude protein" from the total nitrogen by multiplication by 6.25, which factor is too high for the nitrogenous bodies of miso. The increase of the ether extract is, as already stated, not due to a formation of fat but to the origin of organic acids and other substances soluble in ether, and the slight increase of the crude fibre is probably the result of the growth of new fungoid cells in the koji and the mixture during the fermentation.

The course of quantitative alterations which are accomplished in the fermentation itself can be ascertained from our researches only for the last 100 days, as the first analysis was made only 50 days after mixing the materials. In order to compare the results of the analysis from this point of view it is necessary to start with the contents of the first sample analyzed and to reduce the other in such proportions that their contents may accurately correspond to those of the first sample. A calculation of this kind may be based upon the contents in sodium chloride, which exists in the fermenting mass in a large quantity without being subjected to any conversion, the quantitative determination of which affords great security, because it can be carried out with ease and accuracy. Hence we reduced the contents of the 2nd, 3rd and 4th samples to the proportion of common salt contained in the first sample (21.43 parts); for example, the amount of glucose in the 2nd sample, corresponding to the substance of the first sample is found by the equation : $23.35 : 15.28 = 21.43 : X$; $X = 14.02$.

In this manner the following figures were obtained :—

	Contents corresponding to 21. 43 parts of sodium chloride.				Increase (+) or decrease (−), compared with No. 1.			Increase (+) or decrease (−), per cent of the single ingredient of No. 1.		
Age	No. 1. 50 days	No. 2. 85 days.	No. 3. 120 days.	No. 4. 150 days.	85 days.	120 days.	150 days.	85 days.	120 days.	150 days.
Dry matter	100	91.78	82.90	77.20	− 8.22	−17.10	−22.80	− 8.2	−17.1	−22.8
Organic matter	74.03	65.90	57.84	51.26	− 8.13	−16.19	−22.77	−10.8	−21.9	−30.8
Soluble in cold water	65.53	60.14	51.46	47.27	− 5.39	−14.07	−18.26	− 8.2	−21.5	−27.9
Insoluble in cold water	34.47	31.64	31.44	29.93	− 2.83	− 3.03	− 4.54	− 8.2	− 8.8	−13.2
Crude protein	23.90	23.42	24.01	23.77	− 0.48	+ 0.11	− 0.13	——	——	——
Ether extract	12.43	12.62	12.83	13.07	− 0.19	+ 0.40	+ 0.64	+ 1.5	+ 3.2	+ 5.1
Fibre	4.54	4.53	4.49	4.41	− 0.01	− 0.05	− 0.13	− 0.2	− 1.1	− 2.9
Nitrogenfree extract	33.16	25.33	16.51	10.01	− 7.83	−16.65	−23.15	−23.6	−50.2	−69.8
Ash	25.97	25.88	25.06	25.94	——	——	——	——	——	——
Total nitrogen	3.824	3.747	3.842	3.802	− 0.077	+ 0.018	− 0.022	——	——	——
Albuminoid nitrogen	3.037	2.771	2.497	2.279	− 0.266	− 0.540	− 0.762	− 8.8	−17.8	−25.1
Non-albuminoid nitrogen	0.787	0.976	1.345	1.527	+ 0.189	+ 0.558	+ 0.740	+24.0	+70.9	+94.1
Starch, dextrin, etc:	16.62	15.13	9.60	5.66	− 1.49	− 7.02	−10.96	− 9.0	−42.2	−65.9
Glucose	16.40	14.01	8.48	7.28	− 2.39	− 7.92	− 9.12	−14.5	−48.3	−55.6

It appears herefrom in general that the fermentation was accomplished within the last 100 days of the process rather uniformly, its intensity showing no diminution and the losses of dry and organic matter exhibiting the almost regular proportion

1 : 2 : 3 for the intervals of 35 : 70 : 100 days. This indicates that at the end of the 5 months of the whole process the fermentation was not yet complete, but would have probably continued still longer. The destruction concerns most largely the carbohydrates (starch, dextrin, glucose, etc.), the majority of which, probably after saccharification are oxydized. The quantity (20.08 parts) decomposed of them does not, however, cover the whole loss of organic matter (22.77 parts), 2.69 parts at least being left unaccounted for, which fact indicates that still other components, very probably the albuminoids, have some share in the loss of organic substance. Indeed, next to the carbohydrates, the albuminoids are most considerably affected by the decomposition, but the latter does not issue in a liberation of free nitrogen. The crude fibre undergoes so slight a diminution, that we may regard the latter as lying within the limits of experimental errors. It is a natural consequence of the character of fermentative processes that the essential alterations take place chiefly in the substances soluble in water. Hence we notice in the present case that only 4.5 parts of insoluble components disappear, while 18.3 parts of soluble matters are lost. An increase is only observed with regard to the ether extract and nitrogenous non-albuminous bodies, which is in both cases the result of the conversion and decomposition of other substances.

Further information on the course of the fermentation in cases when the preparation of miso differs from that carried out with the material of our preceding researches, may be gathered from the descriptions and analyses given for the 4 sorts of miso in the 3rd part of this paper. It appears from those data that, provided the operations of steaming and mixing are normally performed, the rapidity of the fermentation is principally determined by the *temperature* of the beans. The warmer the mixture when it is transferred to the fermenting vat, the more rapid is the fermentation, a fact which might have been anticipated, since the diastatic and other fermentative processes as, well as the development of fungi of the sort of Eurotium Oryzæ,

are much favoured by heat. The original temperature and the length of fermentation until maturity of the 4 kinds of miso is shown by the following table.

	Temperature of the original mixture	Length of the fermentation
Shiro miso	70—90° C.	4 days
Yedo ,,	35—45 ,,	20 ,,
Inaka ,,	15—28 ,,	7 months
Sendai ,,	15—20 ,,	8—15 ,,

The temperature of the shiro miso speedily diminishes, partly on account of the rapid fermentation, which, of course, soon declines as the fermentable substances are destroyed; partly because it is only made on a small scale, since it does not keep long. We noticed in the fermenting mass 3 days after mixing only 11°C. in a room with a temperature of 6°C. Yedo miso keeps its heat longer, owing to the less intensive, long lasting fermentation. In one case, we found it to have still 23°C. 18 days after mixing. On the other side, Inaka and Sendai miso remain cold for a considerable time; as they are chiefly prepared in winter, they begin to get warm in spring and summer, and remain so until autumn.

The other factors upon which the rapidity of the fermentation depends, are *the proportions of koji, water, and common salt.* For slowly ripening sorts of miso less koji and water, and more salt is taken than for the early sorts. With a large proportion of koji not only more fermentable matter, but also an increased number of fungi are introduced into the mixture, and a copious addition of water diminishes the high concentration which has a retarding influence on the fermentation. The salt, too, when applied in such large doses as in Yedo, Inaka, and Sendai miso, remarkably reduces the rapidity of the fermentation.

The analyses, already referred to furthermore indicate that in the early varieties of miso the dissolution and decomposition of the raw materials does not assume so great an extent as in the late sorts. Shiro miso, which is ready after 4 days' fermentation still contains in the dry matter 16.12 parts of uninverted

carbohydrates and a relatively great quantity of undecomposed albuminoids and insoluble substances, and differs in this respect from the late sorts of miso.

III. Varieties, Composition, and Nutritive Properties of Miso.

As the quality of miso depends greatly upon the manner of its preparation, the kind of cereal and quantity of salt applied, the colour of the product, etc. a great number of varieties of this food are distinguished in Japan, and are known by special names familiar to the consumer and manufacturer. Some of the most common kinds may be briefly described in the following:

1) *Shiro Miso*, white miso, is characterized not only by its white colour but also by its low content of salt and by the short, time it will keep good. For its preparation the beans, large sorts, are steeped and then boiled in water which must be renewed several times in order to ensure the white colour of the product. The rice for the koji must be very well freed from the bran. The mixture of the materials is carried out while the beans are still very hot (70-90°C.), and maturity is complete after 3-4 days' fermentation. The product does not keep longer than about 10 days.

2) *Yedo Miso*, so called from the former name of the metropolis, is prepared from rice koji and soy beans, which are mixed while still hot (35-45°C.) after steaming, when a portion of the salt is added. The other portion of the salt is dissolved in hot water and, after cooling, incorporated with the mixture by vigorous agitation. The koji manufacturers seem to regard this subsequent addition of a cold salt solution (called tane mizu) as an essential feature of the preparation of this sort of miso. The fermentation is completed in summer within about 10 days, in winter in about 30 days, and the product, which has a reddish yellow colour, keeps from 4-15 months according to the season of the year.

3) *Inaka Miso*, country miso, is the richest in salt and is

prepared with the help of barley koji. The beans require a long time for steaming to impart to them the red colour which is desired for this kind, and must completely cool before they are mixed with the koji and cold solution of salt. If this rule is obeyed, the miso will be ripe after 11—12 months. The preparation usually takes place in autumn, the mass then swells up during the summer, and contracts again in the following autumn, a sign that the miso is ripe. It keeps nearly a year. Frequently, however, the mixture is made when the beans are still warm (about 30°C.) in order to accelerate the fermentation. In the latter case the miso is ready for consumption after 4—5 months.

4) *Sendai Miso* derives its name from the city of Sendai in Miyagi prefecture where it is widely prepared, but is frequently also termed *Aka Miso* (red miso). It is late in maturing, of a red colour, and contains much salt. Its manufacture is remarkably different from that of other kinds. The soy beans, of a large variety, are boiled quite soft, finely ground to a pap, and formed into prismatic pieces of 5—6 inches in length, and 3 inches in diameter. The latter are dried in the air, until the surface is sufficiently hard to allow the pieces to be suspended with straw rope under the roof, where they are left to dry up further for about 40 days. Cracks and mould then frequently appear on the pieces, but are said not to deteriorate the product. When they have attained the proper dryness they are washed with warm water, kept well covered for one night in the moistened state in a vat, and pounded on the next day in a wooden mortar until the mealy mass passes through a fine sieve. The powdered beans are then mixed in the mortar with barley koji, salt, and cold water, and finally well stamped into the fermenting vat which is well covered and kept in a cold place. After about 2 months the mass is again worked through with a hammer in the mortar, which process is sometimes afterwards repeated. The fermentation proceeds very slowly, and after $1\frac{1}{2}$—2 years the miso is ready. It is much admired on account of its fine aroma, sweet taste, and good colour, and keeps in

excellent condition for about one year. In the northern part of the main island of Japan every farmer prepares his aka miso once a year and begins to consume it not before 1½ year's fermentation. In other places less care is bestowed on the manufacture, but a method, resembling that of the preparation of Yedo-Miso is resorted to which accelerates the maturity.

Of the other sorts of miso which are, however, only of local importance, may be mentioned *Sano*, *Nagaseyama*, and *Mikawa* or *Sanshiu Miso*. These, and the above four kinds are not eaten in the raw state but are mostly consumed as soup, or used for flavouring other foods. There are, however, also sorts of miso which can be consumed uncooked just in the condition in which they come from the fermenting vat. These are the following:

Kinzanji Miso, named after a Buddhist temple and prepared by fermenting a mixture of soy beans, barley koji, salt, starch-sugar (amé), slices of the egg plant (Solanum melongena), and ginger roots.

Sakura Miso, quite similar to the preceding, but sweeter on account of an admixture of large quantities of starch-sugar or raw cane sugar.

Tetsuka Miso, is common miso with the addition of sesamum oil, roasted soy beans, and slices of the roots of burdock (Arctium Lappa).

Kogo Miso prepared like common miso, but with an addition of rice bran.

The *composition* of the various sorts of miso and their nutritive properties are but little known. The only analyses, 5 in number which I could find in the literature, have not been made by very elaborate methods, and yield but little information. Two of them (No. 1. and 2) were published by E. Kinch,[6] the other by the sanitary bureau of Tōkyō[7]; the figures given

---

6 A classified and descriptive catalogue of a collection of agricultural products. Tōkyō, 1879 (Agricultural Bureau).

7 Yeisei Shiken Iho.

for the percentage composition of the fresh substance are the following:

	1. Shiro miso from Osaka.	2. Aka miso from Osaka.	3. Shiro miso.	4. Aka miso.	5. Inaka miso.
Water	50.73	50.40	55.97	48.54	51.50
Crude protein	5.64	10.08	11.12	15.42	10.71
Crude fibre..................	12.93	8.25	3.83	4.72	4.50
Sugar	17.54	0.61	14.02	11.36	19.15
Soluble carbohydrate	6.58	18.16			
Ash	6.58	12.50	10.14	14.02	8.10
Soluble in water	35.88	34.71	—	—	—
Common salt	5.4	nearly 12	—	—	—
Fat			4.92	5.94	6.04

Researches on the composition of the 4 principal sorts of miso above described were recently made in a more detailed way by Mr. *M. Nagaoka*, assistant in the laboratory of our college, to whom I am also indebted for the descriptions of the manufacturing processes of these and other kinds of miso. The samples for the analyses had all been bought in Tōkyō, also that of Sendai miso, which we were unfortunately not able to procure from Miyagi prefecture. With regard to the manufacture of the 4 specimens we collected the following notes on the proportion of the raw materials[8], age, temperature of the beans when mixing them with the other ingredients, and price per *kin* (=0.601 kilogrms):

	Soy beans.	Koji	Common salt.	Water.	Age.	Temperature of the beans.	Price, Sen.
	to.	to.	to.	to.			
Shiro miso ..	5	6 (rice)	1.5	1	4 days	very hot	22
Yedo ,, ...	5	5 ,,	2	1	20 ,,	hot	13.5
Inaka ,, ...	5	5(barley)	2.5	?	7 months	little warm	16
Sendai ,, ...	5	3.25(rice)	2	?	8 ,,	cold	11

8 1 *to* = 18.04 litres.

The results of the analyses were as follows:—

A. IN THE FRESH SUBSTANCE.

	Shiro miso.	Yedo miso.	Inaka miso.	Sendai miso.
	%	%	%	%
Water	59.27	48.45	50.36	50.16
Dry matter	39.78	49.63	48.57	48.66
Soluble in cold water	22.13	34.25	32.30	32.28
Insoluble „ „ „	17.65	15.38	16.27	16.38
Crude protein	10.18	12.84	13.93	14.29
Ether extract	5.10	5.26	5.52	6.46
Crude fibre	1.99	1.79	2.46	2.31
Nitrogen free extract	14.63	17.81	13.60	13.12
Ash	7.78	11.93	13.06	12.48
Total nitrogen	1.629	2.054	2.229	2.286
Albuminoid nitrogen	1.144	1.180	1.301	1.532
Non-albuminoid „	0.485	0.873	0.928	0.754
Ammonia	0.033	0.042	0.056	0.076
Starch dextrin, etc.	6.31	6.18	4.54	2.72
Glucose	8.32	11.63	8.52	10.40
Ash free from common salt.	1.79	1.64	1.64	1.65
Common salt	5.99	10.29	11.42	10.84
Volatile acid (as acetic)	0.048	0.027	0.022	0.024
Fixed acid (as lactic)	0.160	0.272	0.259	0.139
Alcohol	0.95	1.92	1.07	1.18

B. IN THE DRY MATTER.

	Shiro miso.	Yedo miso.	Inaka miso.	Sendai miso.
	°/₀	°/₀	°/₀	°/₀
Soluble in cold water	55.62	68.99	66.50	65.32
Insoluble " " "	44.38	31.01	33.50	33.67
Crude protein	25.59	25.86	28.68	29.36
Ether extract	12.81	10.60	11.36	13.27
Fibre	5.00	3.61	5.07	4.74
Nitrogenfree extract	37.04	26.79	28.00	26.98
Ash	19.56	23.04	26.89	25.65
Total nitrogen	4.095	4.138	4.589	4.697
Albuminoid "	2.878	2.379	2.679	3.148
Non-abluminoid nitrogen	1.217	1.759	1.910	1.549
Ammonia	0.090	0.085	0.115	0.156
Non-albuminoid nitrogen in °/₀ of total nitrogen	27.52	42.50	41.63	32.98
Starch, dextrin, etc.	16.12	3.38	10.47	5.61
Glucose	20.92	23.43	17.53	21.37
Ash free from common salt	4.51	2.36	3.30	3.39
Common salt	15.05	20.74	23.53	22.26

Miso represents, according to these researches, a salted fermented food with a content of about half its bulk of water. It is distinguished by the great solubility of its constituents in water, which property is a consequence of the vigorous action as well of proteolytic and diastatic ferments produced by a peculiar fungus, as of the processes accomplished in the living cells of the fungus itself. In spite of the decomposition of the albuminoids, carbohydrates and their immediate products caused

by subsequent processes, the finished miso remains rich in both, true albuminoids and soluble carbohydrates (glucose and dextrin), and the losses involved by the destruction are certainly fully counterbalanced on the one hand by the increased digestibility and on the other the dietetic properties, which must be ascribed to some of the products originating during the fermentation. Indeed, as to digestibility, the dissolution of the albuminoids, and saccharification of the carbohydrates, which both take place to so considerable an extent in the manufacture, are essentially the same processes, which would have to be performed by the digestive fluids in the alimentary canal; hence it results that, if the raw materials of which the miso is prepared were directly eaten, they would certainly not be digested with that ease, and probably also not at that rate, which we are justified in ascribing to the finished miso. These considerations are, however, of less significance, as miso is never consumed in large quantities. More importance must be attached to certain dietetic properties, which are acquired by the fermentation. We are in a position to show in a paper, which will be issued ere long, that the decomposition of the albuminoids by the fungus is associated with the formation of certain nitrogenous substances of a character partly similar to and partly identical with that of the active constituents of *beef extract*, and we may add here that similar substances exist also in *shoyu*, a sauce prepared by a fermentation closely resembling that applied in the manufacture of miso.

It is true that the nitrogenous substances of beef extract, and consequently also the so called "extractive substances" of miso and shoyu when eaten in the usual small quantities, are not capable of protecting from destruction any remarkable quantity of the albuminoids which are regularly decomposed in the body for the maintenance of life or the production of energy; at least, researches by C. von Voit on the effect of beef extract and coffee have proved it to be so. This fact does, however, not involve that these substances may not act on the nerves in

a manner beneficial to the whole organism. It results, indeed, from investigations by Kobert[9] that kreatin and hypoxanthin, as well as coffein (theine), have the property of increasing the energy of the muscles, when they are injected subcutaneously, and from researches of Thomas J. Mays[10] we may conclude that the relaxed heart is at once stimulated to activity by solutions of kreatin and kreatinin artificially conducted through that organ. In the same way also the muscles of the stomach and intestines will be affected, and thus digestion will be facilitated. *Miso and shoyu*, which both contain substances of this kind, *act accordingly not only by their content of albuminoids, fat, and carbohydrates, but also as stimulants, and are to be counted in this respect in the same class of food adjuncts or condiments as beef extract.*

The large proportion of common salt, which is necessary, as already explained, to secure a slow course of fermentation and which essentially contributes to the keeping qualities of the food, does not diminish the suitability of miso for human nutrition. The Japanese people, especially the lower classes, whose ordinary food is made up chiefly of vegetable products rich in potassic compounds, are naturally inclined to the consumption of much common salt, and indeed eat more of the latter than westerns whose food is different. Whether this fact be due to mere habit or to a facilitation of the digestion of course vegetables attributed by some authors to common salt[11] or, as Bunge suggested, to the peculiar influence of potassic compounds on the excretion of soda[12], it plainly intimates that a moderate portion of miso soup in the daily bill of fare, even up to a content of 100-120 grms. of fresh miso, does not introduce unnecessarily large proportions of common salt into the body, but simply supplies the demand.

The above figures finally show that miso always contains

---

9 Archiv für exp. Pathologie u. Pharmakologie. 1882, 15. vol., p. 59.

10 Practitioner. 1887, p. 257. Chemiker-Zeitung. 1888, No. 100, p. 1662.

11 Ogata. Archiv der Hygiene, vol. 3, p. 211.

12 Bulletin No. 3 of this college. 1888, p. 7

slight proportions of alcohol and free organic acids. Only when putrefaction sets in after too long storing and the miso is no more fit for human food, an alkaline reaction will probably appear.

Comparing the 4 varieties of miso of which the composition has been given above, we find that the shiro miso which ripens most early is the richest in water and the poorest in common salt. The decomposition of the albuminoids, as shown by the percentage relation beween non-albuminoid nitrogen and total nitrogen (27.52%), though not advanced so far as in the other kinds, has nevertheless attained a remarkable extent, compared with the short time of fermentation. Of the carbohydrates not so much has been destroyed as in the other late varieties, whence the nutritive ratio is still wider than in the latter. The composition of the three other sorts is strikingly uniform in spite of the different proportion and kind of raw materials applied, temperature in the time of mixing the latter, and length of fermentation. Only in the case of Sendai miso, in which the largest relative quantity of soy beans and the smallest proportion of koji is applied, the decomposition of the albuminoids took place with less vigour than in the other sorts.

Experiments on the Effect of Several Nitrogenous Fertilizers on Crops.

BY

Dr. O. Kellner, Y. Kozai, Y. Mori, and M. Nagaoka.

Nitrogenous manures contain their nitrogen either in the form of readily soluble compounds (ammonia or nitric acid), which can be directly consumed through the roots, or they consist of more or less soluble organic substances which must generally undergo decomposition or oxydation into the above compounds before they can be taken up from the soil. The more soluble or decomposable a manure, the greater and more rapid is, of course, its effect, if rain does not wash it down out of reach of the roots.

Nitrates represent a nitrogenous manure suitable to all dry land plants. As they are not absorbed by the soil, but remain freely soluble, and diffuse with great ease through it, the roots can take them up very completely within a short time. Owing to this rapid entrance of much nitrogen into the roots, the young plants have a strong tendency to a rich tillering, but as all of the fertilizer is consumed in an early stage of the growth, the numerous shoots, which require also in later periods of life nitrogenous food, no longer find sufficient of it in the soil, and are thus liable to suffer from nitrogen hunger. Hence if a liberal quantity of nitrates is applied in one dose before sowing, the yield of grain will turn out to be defective in spite of a copious formation of accessory stems.—The great solubility of nitrates endangers, moreover, their effect, because they are liable to be carried by rain so far down that the roots can no longer reach them.

Ammonia is distinguished from the nitrates by its capacity for undergoing absorption in the soil. Hereby it becomes but sparingly soluble in the fluids of soils and is thus protected in the beginning from being washed into deep layers of the subsoil. For the roots it remains, however, soluble enough to be rapidly consumed and to cause copious tillering in a similar way to, and

with but slightly less uneconomical consequences than generally appear after a liberal supply of nitrates. In the soil of dry fields it is furthermore liable to be converted into nitric acid, and as this change is much favoured by heat, a part of it may nevertheless be washed in this form by rain too far down and escape consumption through the roots, particularly in countries like Japan, where the temperature during summer is high and rains are copious and frequent.

Organic materials applied as nitrogenous manures such as fishes, bones, oilcakes, brans, etc., are less soluble than either nitrates or ammoniacal salts. When mixed with the soil, they are first gradually decomposed by a multitude of minute fungi, yielding besides carbon dioxide and water, ammonia and similar bodies, which at their origin, are absorbed by the soil and likewise converted in the course of time into nitric acid. In this way they secure to the plants a constant flow of nitrogenous food, the rapidity of which depends, of course, as well on the facility with which the materials are dissolved or softened and decomposed, as on climatic conditions, especially heat and moisture. The losses caused by copious rains are with organic manures less than with either nitrates or ammonia.

Of the climatic conditions, *heat* and *rain* have, as already stated, a considerable influence on the effect of nitrogenous manures, as on the one hand they accelerate decomposition and nitrification in the soil, and on the other, may cause losses by washing away soluble substances. *The experience gathered in central and western Europe as to the preparation, application, aud rapidity of action of fertilizers is therefore not directly applicable to countries with considerably higher temperatures and copious rainfall.* Considerations of this kind guided us in making in 1888 some experiments on the effect of various nitrogenous fertilizers, in the fields of this college.

The soil on which these researches were carried out, consists of volcanic ashes mixed with some sand of fine grains of a smaller diameter than 1 millimetre. It is very light and porous, but retains the moisture very well, and is rich in humus and

easily decomposable silicates, whence it possesses a high absorptive power for ammonia and phosphoric acid. Compared with others, it ranges certainly among the better sorts of soils of Japan, though it is liable to the formation of sour humus. From chemical points of view, it is remarkable for the almost complete absence of clay (hydrous silicate of alumina) and for its richness in easily decomposable silicates (zeolites), owing to which it gradually solidifies when copiously mixed with caustic lime and kept in water[1].

As the dimensions of field experiments are too large to admit exact treatment and as the results obtained on large plots are usually not reliable enough to allow of generalization, we employed, according to P. Wagner's proposals[2], zinc cylinders of a height of 133 centimetres and a diameter of 60 centimetres open at both ends. These were buried up to 3 centimetres from their upper edge in a level field and uniformly filled to a height of 1 metre with yellow subsoil almost free from humus and being of the same character as the top soil above described. Then uniform black top soil freed by sifting from course roots and stubbles, was weighed out in quantities sufficient to make up in the cylinders a layer of 27 centimetres after gently pressing it in. This soil was mixed with the manures, put into the cylinders, levelled and pressed, whereupon sowing took place. To each vessel we applied 89 seeds of *Chevalier* barley (= 2 hektolitres per hektare) which were equally distributed over the small patches with the help of a disk of zinc plate furnished with parallel lines of holes at distances of 5.3 centimeters from each other. On the seeds we spread a layer of sifted unmanured top soil weighed out for each cylinder, and pressed it well down, because if not pressed, our soil is liable to be thrown up in winter by the formation of long fine crystals of ice (shimobashira).

As to quantities of manures, we followed likewise the general

---

1 Analyses of this soil have been published in Landw. Versuchsstationen 1884, vol. 30, p. 1.

2 Landw. Jahrbuecher 1883, vol. 12, p. 583 and "Thomas Phosphate Powder" by P. Wagner. London, 1887, p. 44.

rules given by P. Wagner. Phosphoric acid, potash, and lime were applied to each plot in so large quantities that the crops found an excess of these nutrients in the soil and that the small quantities of them contained in the nitrogenous fertilizers, could not affect the growth. We applied for the area of 1 hektare (= 1 cho) 100 kilogrms. of phosphoric acid in the form of pure sodium phosphate, 100 kilogrms. of potash as sulphate and 750 kilogrms. of calcium carbonate. The kinds and quantities of nitrogenous fertilizers added to each plot will be found in the following table :—

Kind of manure	Content of nitrogen %	Applied per patch		Nitrogen applied per hektare. kilogrms.
		manure. grms.	nitrogen. grms.	
I. Without nitrog. manure ..	——	——	——	——
II. Ammonium sulphate	20.64	4.11	0.8478	30
III. ,, ,, ...	,,	8.21	1.6956	60
IV. night-soil	0.604	187	1.1304	40
V. ,, ,, ...	,,	374	2.2608	80
VI. Rape cake	5.13	27.55	1.4130	50
VII. ,, ,, ...	,,	55.09	2.8260	100
VIII. Fish manure[3]	8.67	16.29	1.4130	50
IX. ,, ,, ...	,,	32.58	2.8260	100
X. Steamed bone dust	3.69	91.82	3.3912	120

Each single quantity of nitrogen was tested on 3 different plots, 30 cylinders being applied for all the experiments together.

Sowing took place rather late, viz. on November 20th, and germination was very regular, In December, January, and the beginning of February, we had to suspend straw mats over the patches to protect the young plants from injuries by frost. The further development of the barley plants went on without disturbance. Towards the end of April and in May the effect of the fertilizers manifested itself very distinctly, the plots supplied with steamed bone dust surpassed all the others, next came those with fishmanure, then those with night-soil and ammonium sulphate, and finally the plots with rape cake and those without any nitrogenous manure. On July 20th when the grains were

3 Shime kasu.

milk ripe and the lower leaves already yellow and dry, we cut the plants at a height of 1 centimentre above the soil, dried them and determined the total dry matter and nitrogen in them. The results thus obtained were, as follows :—

Nitrogenous manure.	Nitrogen applied per hektare. kilogrms.	Weight of air dry crop. grms.	In the air dry crop. moisture. %	In the air dry crop. nitrogen %	Total dry matter harvested. grms.	Total nitrogen in the crop. grms.
I *a* Without nitrogen	0	140	18.10	0.755	114.6	1.057
,, *b* ,, ...	0	171	14.82	0.755	145.7	1.291
,, *c* ,, ...	0	145	15.50	0.755	122.5	1.095
II *a* Ammonium sulphate	30	208	13.23	0.7765	180.5	1.615
,, *b* ,, ...	,,	197	12.93	0.7765	171.5	1.530
,, *c* ,, ...	,,	194	15.47	0.690	164.0	1.339
III *a* Ammonium sulphate	60	244	14.57	0.7765	208.5	1.895
,, *b* ,, ...	,,	224	13.70	0.7765	193.3	1.739
,, *c* ,, ...	,,	217	13.47	0.7981	187.8	1.732
IV *a* Night-soil ..	40	242	12.93	0.6795	210.7	1.644
,, *b* ,, ,, ..	,,	206	15.10	0.7981	174.9	1.644
,, *c* ,, ,, ..	,,	206	15.30	0.7765	174.5	1.600
V *a* Night-soil ..	80	307	13.50	0.6902	265.6	2.119
,, *b* ,, ,, ..	,,	302	13.70	0.6795	260.6	2.052
,, *c* ,, ,, ..	,,	240	15.70	0.6848	202.3	1.644
VI *a* Rape cake ..	50	164	15.10	0.7010	139.2	1.150
,, *b* ,, ,, ..	,,	164	15.23	0.7657	139.0	1.256
,, *c* ,, ,, ..	,,	162	16.53	0.7334	135.2	1.188
VII *a* Rape cake ..	100	245	15.83	0.7496	206.2	1.836
,, *b* ,, ,, ..	,,	211	15.87	0.8520	177.5	1.798
,, *c* ,, ,, ..	,,	208	17.83	0.9275	170.9	1.929
VIII *a* Fish manure	50	252	14.23	0.6902	216.1	1.739
,, *b* ,, ,, ..	,,	227	16.40	0.8574	189.8	1.946
,, *c* ,, ,, ..	,,	186	16.43	0.7873	155.4	1.464
IX *a* Fish manure	100	335	12.67	0.7172	292.4	2.403
,, *b* ,, ,, ..	,,	315	12.73	0.7603	274.9	2.395
,, *c* ,, ,, ..	,,	280	14.60	0.7765	239.1	2.174
X *a* Steamed bone dust	120	530	13.43	0.8682	458.8	4.601
,, *b* ,, ...	,,	435	12.77	0.7064	379.5	3.073
,, *c* ,, ,, ...	,,	398	12.17	0.7442	349.6	2.962

According to these figures the yield of dry matter and nitrogen is in the average of every three plots that received the same manure, as follows[4]:

Nitrogenous manure.	Nitrogen applied per hektare. kilogrms.	Dry matter harvested.		Nitrogen assimilated	
		grms.	surplus over the plots No I. grms.	grms.	surplus over the plots No I grms.
I. Without nitrog. manure	0	127.6	—	1.148	—
II. Ammonium sulphate ..	30	172.0	44.4	1.495	0.357
III. " "	60	196.5	68.9	1.789	0.641
IV. Night-soil	40	186.7	59.1	1.615	0.467
V. " "	80	263.1	135.5	2.086	0.938
VI. Rape cake	50	137.8	10.2	1.198	0.050
VII. " "	100	183.9	56.3	1.854	0.646
VIII. Fish manure	50	203.0	75.4	1.843	0.695
IX. " "	100	283.7	156.1	2.409	1.261
X. Steamed bone dust....	120	364.5	236.9	3.012	1.864

On considering these results we notice that in all trials except those with rape cake, the nitrogenous fertilizers have remarkably increased the yield of dry matter. In the patches with night-soil and fish manure this increase is fairly proportionate to the amount of nitrogen applied, and in the trials with ammonium sulphate the results approach the same proportion. The strikingly low effect, exerted by the rape cake may be possibly explained as a consequence of an exceptionally high temperature applied to the seed before they had been pressed; if such strong heat is applied as to convert the material into a more or less brown mass, the nitrogenous substances become insoluble and

4 In this calculation the trials Vc, VIIIc, IXc and Xa have been omitted, owing to their considerable deviation from the two other parallel experiments.

cannot be taken up by the roots. We incline to this assumption, because also the following crop (upland rice) was not affected by this manure, as will be described hereafter. On account of this exceptional circumstance we abstain from drawing at present any conclusions on the efficacy of rape cake as a nitrogenous manure.

A good measure for the manurial value of our nitrogenous fertilizers is certainly afforded by the rate of nitrogen assimilated from the manure actually applied, on which subject the following compilation will yield information.

	Nitrogen applied in the manure. grms.	Nitrogen assimilated from the manure. grms.	Nitrogen assimilated from the manure. %
II. Ammonium sulphate	0.848	0.357	42.1
III. " "	1.696	0,641	37.8
IV. Night-soil	1.130	0.467	41.3
V. " "	2.260	0.938	41.5
VIII. Fish manure	1.413	0.695	49.2
IX. " "	2.826	1.261	44.6
X. Steamed bone dust	3.391	1.864	55.0

From these results we may draw the following conclusions :

1) Easily soluble nitrogenous fertilizers, such as ammonium sulphate and night-soil, have less effect than organic nitrogenous manures, such as fish manure and steamed bone dust, if their whole quantity is applied to winter crops before sowing. A considerable proportion of the former is washed by rain down into the subsoil beyond the reach of the roots.[5] Japanese farmers are fully justified in applying the liquid manure in 3-4 doses during the chief periods of growth.

5 Similar observations have been reported by Lawes and Gilbert from the experimental farm at Rothamsted, and P. Wagner likewise advocates the application of chilisaltpeter and ammonium sulphate in spring.

2) Under the conditions of the Japanese climate, well prepared and finely powdered organic manures (fish manure, steamed bone dust) manifest a strikingly rapid action on crops. Of the nitrogen contained in them half or more was assimilated by the first crop (barley).

3) Provided that the whole manure be applied in Autumn before sowing and the effect on the first crop be only taken into account the relative values of the nitrogenous compounds in the 4 fertilizers are as follows, assuming the value of ammonium sulphate to be 100.

Ammonium sulphate.	Night-soil.	Fish manure.	Steamed bone dust.
100	103.5	117.3	137.5

In this case the rate of *nitrogen actually consumed* from the manures was taken as the basis of the calculation. Judging, on the other hand, from the *increase of the dry matter* of the crop caused by the nitrogen of the 4 fertilizers, we obtain the following scale of values:

Ammonium sulphate.	Night-soil.	Fish manure.	Steamed bone dust.
100	120.9	117.0	150.5

It will be noticed that these two scales do not coincide in the case of night-soil and steamed bone dust, but that the increase of dry matter is comparatively greater than corresponds to the rate of nitrogen assimilated. In fact, no close coincidence between the two scales could be anticipated, as the periods of growth during which the nitrogen of the manures becomes available to, and is consumed by, the plants, plays an important part in the production of dry matter. If the nitrogen cannot be assimilated in the proper period of growth, for example, if it becomes soluble too late, the plants may take it up, but it can no more exert any effect. On the other side, it is very probable that the time in which the manure becomes available, may particularly favour the development of the roots at the expense of the stems and leaves, wherefore the dry matter produced by the upper organs

of the plants does not accurately indicate the quantity of the manure that really became active. It must therefore be left to future researches to decide which of the above two scales best coincides with the agricultural values of the fertilizers.

On June 21st, 1889, after the barley had been harvested, the top soil in the patches was digged up, taken out in a spacious vat, the roots and stubbles were cut in small pieces, well mixed with the soil, which was then retransferred into the cylinders. Thereupon 89 seeds of *upland rice* were sown with the help of the perforated disk. Germination appeared to be very uniform in all the cylinders, but when the upper part was about 5 centimetres high, the plants of several patches were injured by beetles which consumed the seeds. We therefore again took out the soil and resowed, but again much damage was done by beetles. On October 1st, when the seeds were still somewhat soft, we cut the crops, but abstained from taking into account the injured patches.

The appearance of the plants in the cylinders indicated throughout the whole time of growth, that the nitrogenous manures given to the preceding crop, had no longer any influence on the rice, and the following weights of the air dry plants likewise showed the available nitrogen of the manures had been entirely consumed by the barley :

	Nitrogen per hektare. kilogrms.	Produce on each plot. grms.	Produce in the average. grms.
I *a* Without nitrog. manure	—	67	67.2
,, *b* ,, ,, ,,	—	73.5	
,, *c* ,, ,, ,,	—	61	
II *c* Ammonium sulphate	30	64	64
III *b* Ammonium sulphate	60	61	65
,, *c* ,, ,,	,,	69	
IV *a* Night-soil	40	61	61
,, *b* ,, ,,	,,	61	
V *b* Night-soil	80	62	60
,, *c* ,, ,,	,,	58	

	Nitrogen per hektare. kilogrms.	Produce	
		on each plot. grms.	in the average grms.
VI *b* Rape cake	50	55·5	51.2
,, *c* ,, ,,	,,	47.0	
VII *c* Rape cake	100	79	79
VIII *a* Fish manure	50	55	55
,, *b* Fish manure	,,	55	
IX *a* Fish manure	100	57·5	59
,, *c* ,, ,,	,,	60.5	
X *a* Steamed bone dust	120	65	67.3
,, *b* ,, ,, ,,	,,	76	
,, *c* ,, ,, ,,	,,	61	

The decomposition and dissolution of organic manures is accelerated, according to our experiments, by the climatic conditions of Japan to such an extent that the nitrogen of fertilizers, like fish manure and steamed bone dust, displays its entire effect within half a year. The rapidity with which ammoniacal manures undergo nitrification, the danger of losing them by rain, and the necessity of applying them consequently in several doses and of spending much labour on this mode of repeated manuring,—all these facts enhance the relative value of the organic nitrogenous fertilizers, such as fish manure, bones, waste products from manufacturing processes, green manures, etc., the whole quantity of which can be safely applied in one dose, and secures a regular and constant supply of nitrogen to the crops. From this point of view it is also not advisable to mix, as some factories are beginning to do in Japan, easily soluble nitrogenous manures, such as chilisaltpeter and ammoniacal salts, with artificial phosphatic and potassic fertilizers, the whole quantity of which latter is generally applied before sowing.

Owing to the small number of zinc cylinders available last year, our experiments have a merely *preliminary* character. We shall, however, fortunately be able to repeat them in the coming season with a greatly increased number of vessels, and hope with the experience gathered in the last year, to attain to greater accuracy than in the preceding researches.

東京農林學校

學術報告

第七號

Imperial College

OF

AGRICULTURE AND DENDROLOGY.

TOKYO, KOMABA, JAPAN,

BULLETIN NO. 7.

Researches

on the Manufacture of various kinds of Tea,

AND

on the Nitrogenous Non-Albuminous Constituents of Bamboo Shoots.

BY

Y. KOZAI.

Assistant in the Agricultural Chemical Laboratory.

明治二十三年三月

Tōkyō, Japan, March, 1890.

Printed by Hakubunsha, Ginza, Tōkyō

Researches on the Manufacture of Various Kinds of Tea.

BY

Y. Kozai.

Besides the true nutrients which must be taken from day to day, and without which we could not live, there are substances mostly called stimulants which although playing an important part in food, are not absolutely necessary to life, and indeed many persons live without them. The substances in the first group are classed by the Germans by the term *Nahrungsmittel*, while those in the second group are known as *Genussmittel*. "Die Genussmittel, says von Pettenkofer, sind wahre Menschenfreunde, sie helfen unserem Organismus über manche Schwierigkeiten hinweg. Ich möchte sie mit der Anwendung der richtigen Schmiere bei Bewegungsmaschinen vergleichen, welche zwar nicht die Dampfkraft ersetzen und entbehrlich machen kann, aber dieser zu einer viel leichteren und regelmässigeren Wirksamkeit verhilft und ausserdem der Ausnutzung der Maschine ganz wesentlich vorbeugt." Indeed the stimulants do not act essentially as nutrients, but they may be calculated as auxiliaries in the great work of maintaining life; and consequently they have found great favour among the nations both present and past. Thus the Egyptians, Jews, Greeks, and Romans regarded alcoholic drinks as among the most precious luxuries of food; the Turks indulge in tobacco; the Indians and Persians are in the habit of drinking (*hashish*); while beer and wine form the favourite drinks of the most civilized nations of the present century.

It is, however, very difficult or rather impossible to draw a sharp line of demarkation between nutrients or foods and stimulants. There is hardly a single article of food which does not contain some constituents which excite the organ of taste or smell, whilst many of the stimulants contain, in addition to their characteristic ingredients, more or less of real nutrients. In general, however, these stimulants, when taken moderately, either excite the nervous system, make our food palatable, stimulate a flagging appetite, or help in digestion.

Among the numerous stimulants used by mankind, tea is one of the most important. It is not only a favourite beverage in the East, but is also used as a beverage in the West. It is, however, in Japan and China that this kind of beverage is popularly used so that there is hardly a single family, however poor it may be, not in possession of a set or two of tea drinking utensils. Moreover, along country roads, mountain passes, and in public gardens there are tea houses where weary travellers or tired visitors refresh themselves with cups of this popular beverage. That tea has become and is becoming a favourite beverage of mankind, need, however, excite no surprise, when we consider the effects it produces upon the animal system.

Tea does not essentiably act upon the organ of taste or smell, like sugar or vanilla, nor does it, like pepper, excite the stomach to an increased secretion of juices, but its chief action is to stimulate the central nervous system after it has got into the blood. " It tempers the spirit, and harmonises the mind, drives out drowsiness and awakens thought, stops hunger and cures repletion, refreshes the body and prevents headache," these are familiar words in praise of the effects of tea, which are, of course, somewhat exaggerated. It is, however, true that a cup of tea is always refreshing, and there is great ease in working after taking tea, but sleeplessness is produced when it is taken in great excess. These effects are probably explained by the fact that it promotes the circulation of blood in the system. Any exertion, either muscular or intellectual, takes place at

the expense of the materials of the body, and the consequence of continued exertion is the accumulation of waste products in the working muscles or organs, which are, in turn, brought into a state of relaxation. But as the blood circulates through the system it carries away these waste products from the tissues, which consequently again acquire activity for further exertion. J. Ranke found that coffee accelerates the circulation of the blood, and this may hold good also in the case of tea. E. Smith observed that tea increases the exhalation of carbon dioxide from the lungs. On the influence of tea on the decomposition of albuminoids in the body there has been much controversy. Thus, Rabuteau found a diminution in the excretion of urea, while E. Roux observed the contrary, as the consequence of tea drinking. Very elaborate investigations by C. von Voit have shown that there is no alteration of the decomposition of albuminoids as a consequence of the consumption of coffee. Hence we may fairly conclude that the influence of tea or coffee on the decomposition of albuminoids in the body is so trifling that it is of no great consequence in the animal economy. Here we must not forget that the circulation of the blood as well as muscular exertion does not keep pace with the excretion of urea, as has been proved by numerous authors, but that they are rather measured by the quantity of carbon dioxide exhaled from the lungs.

There arises, naturally, the question whether there is any thing or things contained in tea, which can explain its actions upon the system and the influence it has gained over the appetite of human beings? Analysis tells us that tea contains, besides the common plant constituents, *theine*, *volatite oil* and *tannin*, which three components are the bases of its actions and influences upon the animal system. Without entering into minute enquiries into the physiological functions of each of these components we may briefly state their actions upon the system. Of theine there is evidence of its poisonous nature, as well for cold, as for warm-blooded animals, and for both herbivora and carnivora. The symptom of theine-poisoning in the case of

animals is characterized by tonic and clonic convulsions with disturbance of respiration and circulation, finally followed by paralysis. When given in large doses, even death takes place, But doses toxicae and letales are not only different in different species of animals, but also in different individuals of the same species, and do not bear an exact proportion to their body-weights. In the case of men, large doses cause uneasiness of the brain, palpitation of the heart, inability to sleep, and even cramp, but the dosis toxica is also different in different persons while the dosis letalis is not known in the case of men. According to interesting researches made by Kobert, theine, like creatine does not only excite muscular activity, but also accelerates the restoration of exhausted muscles to their orginal activity. Hence the action of theine upon the animal system seems to consist essentially in the excitation and subsequent paralysis of the various branches of the nervous and muscular systems, particularly of the muscular or nervous systems of the heart. Indeed, theine tends to increase the blood pressure and acts as a diuretic, hence its use as a medicine in the place of digitalis in certain diseases of the heart and kidneys. Of the aromatic oil of tea little is known at present, though it is one of the most essential constituents of tea, since it is chiefly upon this ingredient that our craving for tea depends. It is, however, probable that it acts upon the nervous system, in addition to its well known exciting action upon the organs of taste and smell. The last active component of tea, tannin, is remarkable for its great affinity for albuminoids. Hence it may cause a certain degree of indigestion by precipitating the ferments of the digestive fluids and also the dissolved albumen of food, and may even attack the mucus membranes of the digestive canals when taken in large excess, though the precipitate produced by tannin is easily soluble in hydrochloric acid which is always present in a small quantity in the gastric juice of a healthy person. But it is a matter of common experience that a large dose of tannin produces pertinaceous obstination, frequently a little nausea and want of appetite, and even obstinate vomiting.

Hypoxanthine and xanthine,[1] though occurring in exceedingly small quantities in tea, may also be considered favourable components of the latter. Indeed, Kobert observed that hypoxanthine has an effect upon the muscular systems similar to creatinine and coffeine. A recent investigation by T. J. Mays has shown that the weakened heart is again thrown into activity by means of an artificial circulation with a solution of hypoxanthine or xanthine. Furthermore, the large quantity of potash contained in tea may act as a slight excitement upon the nervous system, as in the case of beef extract. It is now, evident, without any further explanation that the use of tea in moderate quantities is not only unprejudicial to health, but is a source of comfort in life and a restorative for muscular energy, but when used in great excess especially by those either delicate in constitution, or debilitated by disease, a sense of exhaustion, or inability to sleep and even dyspepsia may appear as a consequence. Of course, any injury which may result from the improper use of this alkaloidal beverage is only transient, and very trifling in comparison with that caused by the consumption of an excess of an alcoholic drink.

It is clear from what has been stated, that the effects of tea upon the system should differ with different kinds of tea. It is, indeed, a matter of daily experience that the better the tea the stronger is its action upon the system, and vice versa. Since good tea can only be prepared from very young leaves liberally supplied with manure, there should be some difference in the composition of the leaves of young and of old, and perhaps also of manured and of unmanured plants. Researches[2] made by O. Kellner in conjunction with K. Oku and K. Ogasawara, have shown that very material alterations take place in the leaf particularly in its earliest periods of

---

1 Baginsky detected hypoxanthine in tea, see Zeitschrift für physiolgische Chemie, Vol. VIII, p. 385. I found guanine, hypoxanthine and xanthine in fresh tea leaves; the full record on this research will be published in one of the following Bulletins.

2 Landwirthschaftliche Versuchs-Stationen, 1886, p. 370.

growth. The conclusions, the author has drawn from his analyses are as follows.

1) The percentage of water in the leaves continually decreases from the spring up to the autumn.

2) Crude protein and nitrogen-free extract regularly diminish, while crude fibre and ethereal extract increase proportionally.

3) Theine diminishes gradually, while tannin increases slightly.

4) Substances soluble in hot water gradually diminish up to a certain period, and then increase slowly.

5) As regards the quantity of ash, there is but a slight fluctuation throughout the year, but its components undergo a remarkable alteration; thus there are a decided diminution of potash and phosphoric acid and a considerable enhancement of lime, magnesia, and iron; furthermore the quantities of soda, manganese and sulphuric acid increase, while the percentage of silica and chlorine remains nearly constant.

Of the second factor which may alter the composition of the leaves i.e. *manuring*, the only trial ever made, so far as I know, is that by J. C. Brown,[1] who made a partial analysis of the tea leaves gathered from the plants supplied with a complete fertilizer and others from unmanured plants. This author concluded from his trial, that although the quantity of leaf grown on the manured portion of the plot was much greater than on the unmanured portion, the leaves, on both portions, contained the same percentage of mineral and organic matters.

Whether the *age of the plant* may have some influence upon the composition of the leaves, is a subject not yet experimented upon, although the opinion that older plants produce better leaves prevails among our tea-planters. Hence the practice of preferring or rather selecting the older plants for the preparation of a superior kind of tea, for instance, dew-drops. O. Kellner tried in conjunction with M. Tanaka and B. Minari to clear up the matter by experimental researches, in which they analysed four specimens of young tea leaves gathered at the same time,

1 Journal of the Chemical Society, 1875, p. 1217.

from plants of different ages growing on the same field, under exactly the same external conditions. The percentage composition of these four specimens was found to be as follows:

Age of the shrubs, years.	No. I. 4	No. II. 7	No. III. 16	No. IV. 20
Water	77.88	76.11	76.08	74.68
In 100 parts of dry matter:				
Crude protein	34.06	37.00	33.06	33.88
Ethereal extract	4.08	4.47	5.43	4.76
Crude fibre	12.47	13.53	15.50	14.33
Nitrogen-free extract	44.22	39.02	40.59	41.46
Ash	5.17	5.98	5.42	5.57
Theine	2.60	2.07	2.88	2.17
Soluble in hot water	33.94	36.64	32.21	32.86
Total nitrogen	5.45	5.92	4.03	5.42
Albuminoid nitrogen	4.31	4.41	2.88	4.10
In 100 parts of pure ash:				
Potash	49.34	49.37	47.81	47.49
Soda	1.08	1.53	1.85	1.94
Lime	6.76	6.07	4.99	4.19
Magnesia	4.97	6.03	8.54	9.68
Mangano-manganic oxide	1.20	1.23	1.31	1.09
Ferric oxide	5.46	3.86	5.16	3.78
Phosphoric acid	19.49	17.70	17.57	16.80
Sulphuric acid	9.67	9.81	7.93	10.39
Silica	0.90	1.17	1.33	1.58
Chlorine	1.58	1.21	1.39	1.68

From these figures, we see that there is no regular variation in the composition of the leaves as a consequence of the age of the plants except the percentage of water which gradually decreases in the leaves of the older plants. Thus, so far as the chemical composition of the leaves is concerned, the prevailing opinion is erroneous; on the contrary, careful pruning

and liberal manuring are necessary to obtain a fair crop of the leaves from the older plants.

Still another factor which exerts an influence upon the composition of tea-leaves is our peculiar method of *screening the plants* from light for a week or two just before the time of picking. By this means, a peculiar fine aroma is said to be conferred upon the tea, so that it is very easy, according to our tea-drinkers, to tell, beforehand, whether or not the tea they drink, originated from screened plants. It is, *a priori*, sure that there should be some difference in the composition of the leaves of normally grown plants and those of screened. In order to solve the problem experimentally, I selected a small plot in a large tea plantation, where a most uniform shooting was observed, a part of the plot was covered with wooden frames so that the plants within were in complete darkness, while the other part was freely exposed to the light. In this state the plants were kept for 3 weeks after which time the leaves in both parts were picked, when the leaves of the screened plants were found to have been completely bleached. A partial analysis of these two specimens of leaves gave the following figures (per cent of dry matter):

	Grown in darkness.	Grown in light,
Theine	4.532	3.784
Total nitrogen	7.835	6.945
Theine ,,	1.311	1.0943
,, ,, per cent of total ,,	16.72	15.75

A special trial has shown that there is practically no difference in the amount of tannin contained in the tea-leaves whether etiolated or green. It seems, therefore, that the chief difference in the composition of these two specimens of leaves lies in the quantities of theine therein contained. This difference is, however, not due to any new production of the said alkaloid in the darkened plants, but is simply caused by the formation of various organic substances, such as fibre, etc. in

the leaves normally grown, and by the destruction of nitrogen-free matters by the continuous respiration in the shaded leaves. It is, indeed, a fact that grapes, apples, and many other fruits differ in flavour according as they are ripened in the shade or in the sun-shine. This may, perhaps, hold good also in the case of the tea plant. But chemical analysis, in its present state, is far from being able to decide such a delicate question. Hence we may only conclude from the result of the analysis that the tea originated from the darkened plants acts more strongly upon the human frame than that from the normal plants.

Before communicating the results of my main research, it is worth while to describe the outline of the methods of preparing the principal kinds of Japanese tea, since the literature on the manufacture of tea is not abundant in the Empire, and is still less so in foreign countries.

I. Green Tea.[1]

The preparation of green tea consists of the following operations.

Steaming. This operation is resorted to in order to deprive the leaves of their elasticity, and to remove the raw flavour common to all green leaves. The action of steam is also the cause of the preservation of the green colour of the product. This operation is very simple, yet a certain degree of personal experience is required to conduct it properly. The utmost care must be taken not to steam the leaves too little or too much. By under-steaming the leaves are not sufficiently softened, and consequently they are liable to be broken during the subsequent operations, and the tea made therefrom has the original raw flavour. By over-steaming, the favourite

1 By the term green tea, we mean *sencha* (infusion-tea.), which though most commonly known by foreigners under that designation is different from that of the Chinese, the latter being similar to our *kamairi* (pan-roasted tea) to be afterwards described.

green colour is damaged, becoming yellowish, and the tea prepared therefrom is not sufficiently strong. It is only from properly steamed leaves that tea with a delicate colour and a fine aroma is prepared. But as the raw flavour can with difficulty be removed, while the aroma can be easily produced, by refiring, over-steaming is to be preferred to under-steaming.

As regards the practice of steaming, the leaves are put in a round wooden tray with a bamboo bottom, which is then put upon the mouth of an iron cauldron set in plaster over burning fuel. A wooden lid is immediately put upon the tray, and steaming is commenced. This tray is about 1½ *shaku*[1] in diameter and receives about 60 *me*[2] of fresh leaves. During steaming the leaves are agitated once or twice, so that they shall be uniformly affected by the steaming. This is, indeed, of vital importance, since it easily happens that while some of the leaves are sufficiently or even excessively steamed, others are but insufficiently steamed[3]; the tea prepared from such mixed leaves, when brewed, gives an infusion with a reddish shade, which is regarded as a blemish by tea-drinkers. The time of steaming is, of course, dependent upon the nature of the leaves, the younger and more tender the leaves, the shorter the time required, and vice versa, being generally half a minute. A thermometer at the bottom of the tray generally indicates 80—90°C, sometimes even 95°C. The proper degree of steaming is generally determined by the consistency, as well as the smell of the leaves. In practice, the leaves are regarded as sufficiently steamed when they incline to adhere to the sticks used for stirring and when the smell[4] issuing from the steam-

---

1 1 *shaku*=0.30303 metre.

2 1 *me*=3.7565 grams.

3 Such leaves soon undergo a sort of fermentation, their lively green colour becoming dirty brown.

4 A gradual transition of flavour is observed in steaming the leaves. At first, only a raw flavour comes out from the leaves, which soon gives way to a sweetish flavour, the latter being followed by an aromatic taste, this again passing away when steaming is continued for a long time. Such excessively steamed leaves produce tea totally destitute of a fine aroma.

ing tray is somewhat aromatic. The sufficiently steamed leaves are immediately tumbled over a wooden table or upon a straw mat, and cooled, without delay, by means of a fan. By this means, the steam imprisoned between the leaves is driven out, thus saving much time and labour in the subsequent process of drying. The leaves thus treated are carried to the firing room.

Rolling and Drying. These two operations are, for the most part, performed at the same time, since rolling is done in the furnace itself. Rolling is intended to give the leaves a curled appearance, and at the same time, to impart to them the property of being easily infused. It is, indeed, during this simple mechanical operation, that the juice is expressed from the cellular tissues of the leaves and impregnated upon their surface. An investigation has shown that such tea is much more easily infused than the leaves simply dried. It is also during this and the following operations that the fine aroma so characteristic of tea is produced, since it does not appear to be present as such in the fresh leaves. We are in complete ignorance of the origin and formation of this appetite-exciting ingredient, nay of the nature of the latter itself. It is, however, highly probable that it originates from an oily substance, somewhat volatile or decomposable under the boiling point of water, and soluble both in alcohol and ether, certainly existing in the inter-cellular spaces of the leaves, since I have observed that the tea prepared from leaves either unduly steamed, or extracted with either of the above solvents, is entirely destitute of pleasant scent. Moreover the production of aroma is not caused by oxidation, but more probably by a simple decomposition of the substance by heat, since I have observed that the fine flavour is engendered either when the leaves are heated in a current of carbon dioxide, or in one of ozonised air.

As to the practice of rolling and drying, the apparatus first requires mention. It consists of a furnace of simple construction, built of bamboo and mud, being generally 6 *shaku* long by 3 *shaku* broad, and 3 *shaku* high. Six or eight such furnaces

are arranged side by side in a firing room. At first, 2.5 *kwamme*[1] of charcoal are well heaped upon the bottom of each furnace, and it is then made to glow. Soon afterwards, two or three bundles of rice straw are put upon the glowing charcoal and allowed to burn into ash, so that the latter completely covers the former, thus preventing air from direct contact with the charcoal, and thus securing an uniform and continued action of heat. As this furnace is very rough in structure, air can freely enter from all sides. In the case of a good furnace, a special opening for the entrance of air is made at the side. Thus arranged, three strong iron bars are put across the furnace, upon these bars is put a square iron wire gauze, which receives, in its turn, a wooden frame with paper bottom,[2] upon which the whole operation is conducted. This frame must be so well fitted to the furnace that when properly arranged there should be left no large open space between the two. In the case of preparing a superior tea, starch paste is thickly rubbed upon the surface of the paper to give it a smoother face to prevent the formation of dust and ~~and~~ rough-faced tea. Such furnace is, however, only employed in the final drying of the twisted leaves. The furnace with the glowing charcoal in its heart is now ready for the reception of the leaves. At first, about 500 *me* of the properly steamed leaves are placed upon the paper tray, and a workman begins to do his work. In the beginning of the operation he simply scatters the leaves by tossing them in the air without any attempt at rolling or pressing. Soon afterwards, however, he proceeds to roll the leaves

---

1 1 *Kwamme*=3,7565 Kilograms.

2 Sometimes an iron plate is employed instead of paper, since the latter is very liable to be damaged during the manufacture. But the tea prepared with an iron tray has a blakish tint not esteemed by our countrymen. Hence it is recommendable to use the iron tray for preparing tea of an inferior description or destined for export. The following advantages may be enumerated for the use of the iron tray in the furnace.

1 Great economy in time and labour.

2 The tea made with the iron tray is said to assume a finer appearance by refiring.

between his palms by moving his hands backwards and forwards. This he does, at first, slowly and lightly, but gradually more firmly, and finally he does so with all his force, taking care not to allow the leaves to ball. This process is continued until the leaves have lost most of their moisture, becoming darker in colour and assuming somewhat the shape of twisted paper strings, when they are taken out of the furnace and transferred on to a second furnace of the same construction in quantities of about 750 *me* of fresh leaves. Then they are subjected to a second rolling, which must be conducted more carefully than the first, and for which generally a more skilful workman is employed, since it is chiefly during this second rolling that a fine aroma, a delicate colour, and a nice twist are bestowed upon the tea. In this process, as in the former, the leaves are rolled between the palms but not so strongly as in the first rolling, since the leaves are now very sticky and liable to twist together if they are strongly rolled. After a while, the leaves become no more sticky and lose their moisture, when they are again rolled very strongly but most carefully, since it is at this period that the leaves take their final twist. When the leaves are nearly dried, the rolling is interrupted and the dust is separated, since the latter is easily charred, and thus might impart to the tea a disagreeable burnt smell. The temperature of the first and second furnaces fluctuates between 75—85 sometimes rises to 94°C.[1] The well twisted leaves freed from dust are now transferred to a third furnace where the temperature is a little lower than in the second; viz about 65—75°C. There the leaves are not rolled at all, but simply spread upon the paper tray and frequently turned over, so that they are uniformly affected by the heat. There they are left until completely dried, when they are either directly put in a large earthenware jar, or more generally again subjected to a further dessication. For this purpose, all the glowing charcoal is taken out of the furnace, and about 2.5 *kwamme* of the dried leaves are spread upon a

1 Of course the temperature of the leaves is much lower, especially at the first stage, but approaches that of the furnace as they become drier.

thick paper placed upon the furnace. There the leaves are left until the next morning. The temperature in the furnace should be rather low; viz. 35—40°C. One workman can prepare, as a day's work, 4 *kwamme* of a fine tea, 5 *kwamme* of a medium, and 6 *kwamme* of an inferior tea. From 1 *kwamme* of fresh leaves generally 0.23 *kwamme* of tea is obtained.

Sortimenting. The tea thus prepared is subjected to sifting with an ordinary Japanese sieve of large meshes. The latter is suspended from the ceiling by a long cord and moved backwards and forwards lightly pressing the tea therein with the palm of the hand. By this means the petals are separated from the blades, both passing through the sieve, while the large open or untwisted leaves remain behind. The leaves, together with the petals, etc., are winnowed by a sort of shallow basket, by which dust as well as open leaves are blown off. Finally the remaining rubbish is picked up by hand. Now comes the use of a set of sieves of the following description.

No.	Diameter in *shaku*	Size of meshes in *bu*[1]
2	2.2	3.0 in square.
3	2.1	2.2 ,,
4	2.0	2.0 ,,
5	1.9	1.8 ,,
6	1.8	1.5 ,,

The depth of all these sieves is equal, being 3.8 sun.[2] One or other of these sieves is used according to the quality of tea. For an inferior sort, the sieves No. 2, 3, and 4 are used, the sifting with these sieves being repeated twice or even thrice with each. For a medium sort, the sieves No. 4. and 5. are employed, and the sifting with each sieve is performed twice. For a superior sort, the sifting with the sieve No. 6 is repeated twice. The sieve No. 1 is only used for quite an ordinary tea, while for an extra-fine sort, the sieves No. 7, 8, 9, and 10 are sometimes employed. The tea thus sortimented is once more fired at a moderate heat for a few minutes (about 7 minutes)

1 1 *bu*=0.01 *shaku*.

2 1 *sun*=0.1 *shaku*.

then winnowed to separate dust, and immediately put either in a large earthenware jar, or in a large wooden box, and well closed. The tea destined for export is not generally so minutely sifted as that for home-consumption, but immediately after the preparation, the tea is freed from dust and petals, the latter by hand, and is packed in a large wooden box. In this state it is carried, through the hands of the tea-brokers, to the shipping ports, where it is again fired, sortimented, and packed up in the godowns of the exporter.

II. Pan-roasted tea (Kamairi.)

This method of preparing tea is now but seldom resorted to, although until about 250 years ago, it was the only method for preparing tea then known to our countrymen. The following from the famous Kaempfer's "Geschichte und Beschreibung von Japan" will prove the fact. "Die Bereitung besteht darin, dass die frisch gepflückten Blätter auf eisernen Platten geroestet, und noch wenn sie ganz heiss sind, mit hohler Hand auf Matten gerollt werden, um sie kraus zu machen." Indeed in Kaempfer's time, this method seems to have been very extensively practised. In the preparation of tea of this description, the fresh leaves are directly put into an iron or bronze round pan over a brick wood-fire where they are stirred by means of a flat-bladed stick, so that they are equally affected by the heat without being in the least degree burnt. After five or six minutes' roasting, the leaves become flaccid, when they are taken out of the pan and rolled with the hands upon a wooden table commonly covered with a mat of *Juncus communis*. They are then again thrown into the pan more moderately heated where they are kept in circular motion without intermission. This alternate roasting and rolling is repeated seven or eight times before the leaves become completely dried. The tea thus prepared is of a yellowish or olive green colour with a fine twist.

III. Flat Tea (Tencha).

This kind of tea is characterized by not being twisted at all, like all other kinds of tea, but as its name implies, it preserves the original flat shape of the leaf. It is now prepared only to a very limited extent. To prepare tea of this description, the leaves from a special tea plantation, (the so-called covered garden[1]) are used. The leaves most carefully gathered, are, before being subjected to steaming, freed from broken or old leaves, dust and rubbish, and only the best ones are steamed. For firing the leaves, in which process the greatest possible precaution is taken, no iron object is allowed to touch the leaves, since it might spoil their fine verdant tint. In general, two or three bamboo sticks are put across the furnace, upon which is a net of split bamboo. Thus arranged, about 300 *me* of the properly steamed and well cooled leaves are thinly spread upon large thick paper, and the whole is placed upon the bamboo net, resting upon the furnace. During firing, the leaves are not rolled at all, nor are they touched with the naked hand, but are simply and very carefully collected by lifting the paper and again spreading by means of bamboo sticks. This alternate collecting and spreading is repeated until the leaves become nearly dried, when they are removed from the furnace, fanned, and finally freed from broken or yellowish leaves. Only the best leaves are again fired in the above way until they are pretty dry. It is necessary during drying, to keep the temperature of the furnace as uniform as possible. Finally the still remaining moisture is removed by exposing the leaves to a very gentle heat during the night. Next morning, the leaves are examined, and when they are completely dried, they are sortimented into three classes and kept for sale. The leaves thus prepared are of a favourite verdant colour. For preserving them, the leaves are put into a small tin pot with double stopper, which is again kept in a large box of *Paullownia imperialis* filled with inferior tea. In case of need the

1 In the garden the plants are kept in darkness by means of straw mats for a week or two just before picking.

leaves are ground to powder and drunk with the infusion for which a solemn tea ceremony (*cha no yu*) is required. Hence this kind of tea was much used by priests and nobles to whom time was not money.

IV. Black tea.

The method of preparing black tea here practised is essentially the same as that employed in other tea producing countries, and consists of the following operations.

Withering. The agent for withering the leaves in the preparation of black tea is the sun, fire being seldom used, and steam never. This is important, since the steamed leaves can not be properly fermented. As to the practice of withering, the fresh leaves, immediately after they have been gathered, are spread in a thin layer upon a straw mat or large tanned thick paper and exposed to the sun, being frequently turned over so as to be uniformly withered. The duration of sunning is dependent, as well upon the thermal intensity of the sun as on the character of the leaves. In general an hour's exposure is sufficient. This simple mechanical operation aims also, in this case, at depriving the leaves of their elasticity. It is also of vital importance to wither the leaves properly, for the judgment of which the following points may be mentioned.

1). Fresh or under-withered leaves have elasticity enough to spring back to their original shape when pressure is removed, while properly withered leaves take any form whatever.

2). The petals of fresh or under-withered leaves will break upon bending them double, while those of properly withered leaves will bend without breaking.

3). Fresh or under-withered leaves give a peculiar cracking noise when pressed together in the hand and held near the ear, while properly withered leaves do not do so.

In practice, however, even these simple tests are unnecessary, since a little practice will enable the layman to judge the

proper degree of withering simply by a glance at, and a touch of, the leaves. In cloudy or rainy weather we can, of course, not make use of the sun for withering the leaves, but are compelled to do so by artificial heat. For this purpose a shelf of bamboo sticks is built over the furnace and the leaves thinly spread upon rough cloth are put upon it. There they are allowed to wither slowly by the gentle heat ascending from the furnace. Withering in hot pans is also resorted to. The next operation to which the withered leaves are subjected is

Rolling. This operation is resorted to for the same purpose as in the case of green tea. Rolling on a coarse straw mat is sometimes done. This must, however, be strictly avoided, since not only many of the leaves are broken, but also a portion of the sap flows out and is absorbed by the mat. The most essential point in the process of rolling is to give the leaves a good twist without losing much sap. It is on the sap that the strength of tea is dependent, so that the more sap is lost, the weaker is the product. Formerly rolling was exclusively performed by hand, but recently a simple rolling apparatus has been invented, which is generally employed in the manufacture of black tea. It consists of a strong wooden rectangular box with a sliding lid provided with handles. The bottom of the box, as well as the inner face of the lid, is made rough by steps cut in the wood, and upon the ribbed face of the lid a coarse cloth is nailed. About 250 *me* of withered leaves are placed between these two rough faces and there they are rolled together by backward and forward motion of the lid. After sufficient rolling, the leaves are subjected to fermentation. It is advisable, though rather tedious, to pick out open or untwisted leaves, since the tea mixed with such leaves fetches but a low price in the market.

Fermenting. This is the most important operation in the manufacture of black tea, since the quality of the tea is influenced much more by this than by any other operation. Indeed, it is chiefly during this operation that the leaves lose their disagreeable raw smell, and acquire their characteristic

fine flavour and favourite tint. As already mentioned, the leaves when once sufficiently steamed do not undergo fermentation, hence it is probable that this is caused by an organism or the like adhering to the surface of the leaves. For putting this supposition into an experimental base, a certain quantity of the leaves was sufficiently steamed and allowed to ferment. It was found that the leaves did not suffer any visible alteration after one hour's exposure to sun-shine, while in a parallel trial sun-withered leaves acquired the characteristic brown tint after the same interval. This alteration of colour can, however, not be taken as a decisive proof of the setting in of fermentation, since most of the chlorophyll may have been decomposed by a long action of steam, and since the decomposition product or products may be more indifferent than chlorophyll itself, which may produce brown colouring matter in combination with organic acids or substances of an acid nature ready formed in the leaves or formed by the act of fermentation. It is a well known fact that an addition of a little acetic, citric, tartaric, or malic acid, or even of an acid salt, to an alcoholic solution of chlorophyll produces a yellowish green or brownish green colour. In the case of leaves rich in tannin as tea leaves the presence of any other acid is not necessary for the formation of a brown colouring matter, since tannin itself acts upon chlorophyll in a similar way as all other acids. According to the observation of Wiesner, a concentrated alcoholic solution of chlorophyll assumes a greenish brown colour, when mixed with much tannin, and the mixture throws down a dirty brownish precipitate when exposed to the air in a shallow basin. This brown substance is regarded as a compound of tannin with oxydized chlorophyll. C. Kraus assumes that a brownish black colouration in the dead leaves rich in tannin may be dependent upon a direct action of tannin upon chlorophyll. It is, however, only after the death of the cells that such an alteration in colour takes place, since chlorophyll granules, so long as the cells are living, are enveloped with living protoplasm which is impermeable to numerous substances,

colouring matters, salts, etc, and perhaps also to acids and acid salts, as Wiesner assumes. Now it is quite certain that an alteration of colour soon takes place, when the contact of chlorophyll granule with an acid sap is favoured by pressing and crushing of the leaves, as in the case of the preparation of black tea. Hence, the alteration of colours can not be calculated as a decisive proof of fermentation. A more certain measure for fermentation is, perhaps, the observation of temperature. I observed in the above trial an increase from 20 to 26.°6C, in the specimen with withered leaves, and only 20-22[1]C. in the steamed leaves. It is hardly necessary to add that the infusion of the former had a reddish brown colour, while that of the latter shewed a yellowish tint. Hence, it is highly probable that the fermentation might be caused by a living organism. Of course many experiments must be made before bringing forward the above conjecture as indubitable truth. Of the nature of fermentation I know not with certainty, but it is highly probable that it is of an acid nature, since according to the manufacturer, over-fermented tea has a sour taste. Indeed, I have found a minute quantity of a volatile acid in the black tea prepared by myself for analysis, but I could not identify its nature because of the small quantity.

As to the practice of fermenting the leaves, there are two systems adopted in this country. The first system consists in making the twisted leaves into balls with a diameter of 3-4 *sun*, arranging many such balls, side by side, in a shallow bamboo tray, covering them with white cloth, and placing them in a sunny place. The second system is to spread the leaves in a bamboo tray, and press them together. They are also then covered with white cloth and put in the sunshine. It is of vital importance to ferment the leaves to the proper extent. By under-fermentation the raw flavour is not

---

1 This might partly be attributed to the large quantity of water in the steamed leaves.

entirely removed, while by over-fermentation much of the fine flavour is lost and even a sour taste is conferred upon the tea. The best token for judging the course of fermentation is the colour of the interior of the ball or layer. In general, fermentation is interrupted when half the twisted leaves inside the ball shall be rusty red and half of them green. The external surface of the ball does not give any sure sign of the advancement of the fermentation, its colour being varied according to the extent to which the leaves were withered; viz, dark greenish red with over-withered leaves, and greenish yellow with under-withered leaves. The duration of fermentation is, of course, governed by the temperature of the air as well as the nature of the leaves, the higher the temperature, or the more succulent the leaves, the quicker the fermentation, and vice versa, being generally 40-60 minutes. The best temperature is generally said to be 40°C, since, though at higher temperatures, fermentation goes on more quickly, there is a risk of going too far with a little negligence.

I must not pass over in silence a preliminary trial on the fermentation of the leaves, consisting simply of the observation of the temperatures of the ball and of the air. The following are the results.

Duration.	Temperature, °C. of the interior of the ball.	Temperature, °C. of the air.	Increase. °C.
At the commencement	29.5	27.0	+ 2.5
after 15 minutes.	30.5	26.5	,, 4.0
,, 20 ,,	31.5	25.5	,, 6.0
,, 70 ,,	33.25	24.75	,, 8.5
,, 110 ,,	34.5	24.0	,, 10.5
,, 150 ,,	33.0	22.0	,, 11.0
,, 190 ,,	32.0	22.0	,, 10.0
,, 230 ,,	31.5	22.0	,, 9.5
,, 270 ,,	30.0	22.0	,, 8.0
,, 310 ,,	29.5	22.0	,, 7.5
After 9 hours from the last observation	23.5	21.0	+ 2.5

Thus, we see that the fermentation went on first quickly, afterwards more slowly, and arrived at the maximum after 2½ hours. I have observed that the career of the fermentation and the alteration of the colour proceed simultaneously. At first, the leaves were, of course, quite green, but they became more and more brownish, and after 2½ hours the whole mass was completely brown, when the temperature attained the maximum. Judging from the appearance of the leaves, the proper degree of the fermentation was already attained after 70 minutes, hence in practice the fermentation is interrupted, when it has run about midway.

Sunning. For this purpose, the properly fermented leaves are thinly spread upon a straw mat or tanned thick paper and exposed to the sun. This operation is said to interrupt the career of fermentation. In reality, however, a slow fermentation still takes place inasmuch as the greenish colour of the leaves becomes gradually blackish. During this operation, the leaves are collected and re-spread frequently, so that they shall be uniformly affected by the sun. This operation is considered as sufficient, when all the leaves assume an uniform blackish tint. The duration of sunning is, of course, dependent upon the thermal intensity of the sun and the nature of the leaves. After the process, the leaves are generally once more rolled. With bright sunshine, an hour, or even less, is sufficient. In rainy or cloudy weather a furnace answers the purpose.

Firing. This is the operation to which the sunned leaves are subjected. The furnace most commonly employed, consists of a cylindrical bamboo basket open at both ends and narrow in the middle, somewhat in the form of a lady's corset. It is about 2.2 *shaku* in height and 2 *shaku* in diameter. The narrow part of the basket is lined with a piece of a bamboo stick which acts as a supporter for a round bamboo tray upon which the leaves to be fired are spread. In commencing the operation, the leaves are thinly spread upon the tray just mentioned, which is then put into the cylindrical basket, and

the whole is transferred carefully over a brazier with glowing charcoal. The temperature of the leaves is, at first, about 65°C or even lower, but gradually it increases as the moisture is driven out, and rises to 75° or 80°C towards the close of the operation. It is of vital importance to turn over the leaves so that they shall be well and uniformly dried. To do this, however, the basket with its contents is carefully removed from the brazier and the leaves are transferred into a similar bamboo tray, mixed, thinly spread and again put into the basket, which is then placed over the brazier. This operation is again and again repeated, until the leaves become so brittle that they can be easily broken when lightly pressed between the fingers. We must strictly guard against touching the leaves while they are upon the brazier, since dust or broken leaves would fall through into the fire, and the smoke thus engendered would spoil the aroma of the tea, giving the latter an unpleasant flavour called "smoky burnt" by tea-brokers. Hence it is advisable to paste paper upon the tray. The manufacture is now completed, and the tea thus prepared is then freed from all red leaves, and afterwards subjected to sifting, for which a set of sieves of different meshes is used. The tea is generally arranged into three classes, namely, pekoe, souchong, and bohea, according to the size of the leaves. Previous to preserving, it is again fired for a few minutes at about 75° C.

Besides these, we have several other kinds of tea, such as sun-dried (partly dried in the sun to save fuel) basket-dried, (dried in the cylindrical basket above mentioned instead of the proper furnace), and solong (prepared according to the method practised in Formosa). But these kinds are manufactured to a very limited extent, and only in very rare cases, so that their methods of preparation are not worthy of mention.

Having described, at some length, the methods of preparing the principal Japanese teas, I shall proceed to communicate the results of my investigation which was conducted in the following way. A large quantity of young tea leaves was

carefully collected from a part of a large tea plantation where the most uniform shooting was observed. The leaves were then thoroughly mixed together and treated as follows.

1) 500 grs were immediately dried at 85°C.
2) 1500 ,, ,, made into green tea.
3) 1500 ,, ,, manufactured into black tea.

In these cases the manufacture was conducted with the utmost care, so that there could be no loss of material, save that which is unavoidable; viz., the adherence of the sap to the hands of the workman and apparatus.

The following was found to be the percentage composition of the dry matter of these three specimens.

	Original leaves.	Green tea.	Black tea.
Crude protein	37.33	37.43	38.90
Crude fibre	10.44	10.06	10.07
Ethereal extract	6.49	5.52	5.82
Other nitrogen-free extract	27.86	31.43	35.39
Ash	4.97	4.92	4.93
Theine	3.304	3.200	3.300
Tannin[1]	12.91	10.64	4.89
Soluble in hot water	50.97	53.74	47.23
Total nitrogen	5.973	5.989	6.224
Album. ,,	4.107	3.937	4.106
Theine- ,,	0.956	0.926	0.955
Amido- ,,	0.910	1.126	1.163

The following figures will show how much of each ingredient of the dry original leaves remained in the teas after preparation.

1 Calculated as gallotannic acid as in all other cases.

	Original leaves.	Green tea.	Black tea.
Dry matter	100.00	98.64	95.47
Crude protein	37.33	36.92	37.14
,, fibre	10.44	9.92	9.61
Ethereal extract	6.49	5.44	5.56
Other nitrogen free extract	27.86	31.01	33.77
Ash	4.97	4.85	4.72
Theine	3.304	3.156	3.141
Tannin	12.91	10.50	4.67
Soluble in hot water	50.97	53.01	45.09
Total nitrogen	5.973	5.908	5.942
Album. ,,	4.107	3.878	3.919
Theine- ,,	0.956	0.913	0.909
Amido- ,,	0.910	1.117	1.114

Hence of 100 parts of each constituent, the following loss (—) or gain (+) took place.

	Green tea.	Black tea.
Dry matter	− 1.36	− 4.56
Crude protein	− 1.70	− 0.61
,, fibre	− 4.98	− 7.94
Ethereal extract	−16.18	−14,33
Other nitrogen free extract	+11.31	+21.21
Ash	− 2.42	− 3.01
Theine	− 4.49	− 4.92
Tannin	−18.67	−63.82
Soluble in hot water	+ 5.96	−11.69
Total nitrogen	− 1.08	− 0.61
Album. ,,	− 5.57	− 4.58
Theine- ,,	− 4.49	− 4.92
Amido- ,,	+22.75	+22.42

From these figures we may draw the following conclusions.

1) The loss of material caused by the preparation is rather slight, amounting in the case of green tea, to 1,36%, and in that of black tea, to 4,53%, of the total dry substance applied.

2) Crude protein suffers, in both cases, a slight diminution principally owing to the mechanical loss of theine and other nitrogenous substances.

3) Fibre shows a small loss owing to its destruction during the preparation.

4) The loss of ethereal extract is somewhat remarkable owing to a conversion of a part of the tannin into a form insoluble in ether, as a consequence, nitrogen free-extract shows a remarkable increase. The fact that the loss of ethereal extract in black tea is less than in the green, indicates the formation of organic acids[1] and other components soluble in ether during the fermentation of the leaves.

5) Ash too suffers, in both cases, a slight loss, owing to the mechanical loss of the sap in which it is partly dissolved.

6) A trifling loss of theine may also be attributed to the same source of loss rather than to its sublimation during firing.

7) The destruction chiefly concerns tannin, of which disappear from 100 parts of dry matter applied 2,41% in green tea, and 8.23% in black. It is destroyed chiefly during the process of rolling and drying; and in the case of black tea, fermenting is the most energetic agent for the destruction of tannin. It is, indeed, true that it is very prone to alterations, since I have found, that even during the mere drying of tea leaves in the sun, a slight, but appreciable quantity of tannin is destroyed.[2]

8) Extractive matter shows a noticeable enhancement in the case of green tea, and a somewhat remarkable diminution in that of black. According to the investigations of various authors[3] green tea generally contains more soluble substances than black. This is most probably owing to the conversion of large quantities of soluble tannin into insoluble

---

1 I found a minute quantity of a volatile acid in black tea though I failed to identify its nature.

2 From 100 parts of the tannin, 97,70 parts were found in the leaves dried in the sun.

3 See König's Nahrungsmittel. Vol. II. 2. edition. p. 618-619.

phlobaphene[1] and also the decomposition of organic matters by the organized ferments during the fermentation of leaves, while in the case of green tea, though a fraction of tannin is decomposed, it will not suffer so far-reaching a change as in that of black tea, and the decomposition-products thus formed may be soluble in water.

9) A slight decrease of albuminoid-nitrogen and the relative increase of amido-nitrogen, in both kinds of tea, indicate the decomposition of a small fraction of albuminoids into simpler nitrogenous bodies even during the simple process of preparation.

In short, black tea suffers more material alterations during preparation than green, since in the former the leaves are subjected to fermentation, while the manufacture of the latter consists entirely of mere mechanical manipulations.

As already stated, export tea is always re-fired in the godowns of the exporter. This process is resorted to in order to drive out the excessive moisture from the tea and to destroy the germs which, particularly in the presence of much moisture, would exercise an injurious action upon tea during a long voyage. Ordinary tea contains generally 10-11% of moisture, which is reduced to 3-4% by refiring. But as this process is conducted at a high temperature, there should be some alteration in the composition of the tea. An investigation by O. Kellner and Y. Mori[2] on the above subject shows that the refiring process does not deteriorate the quality of tea, as was supposed by many, but on the contrary it increases the fine aroma and diminishes the astringency while a slight loss of theine is of no practical moment. It is, however, during the process of refiring that the shameful practice of facing tea is performed. Both black and green teas are thus generally artificially coloured or faced. The pigmentary matters commonly employed in the

1 I have observed in the extracted leaves of black tea a noticeable quantity of phlobaphene.

2 Mittheilungen der deutschen Gesellschaft für Natur- und Voelkerkunde Ostasiens, Vol. IV, no. 39, 1888, p. 416.

case of green tea are Prussian blue and soap-stone, these are mixed in various proportions, so as to produce different shades of blue and green. Such mixtures as I know to be employed in some tea refiring factories consist of the following proportions.

Mixture.	Prussian blue.	Soap-stone.
No. 1	13 grs.	500 grs.
,, 2	9 ,,	,,
,, 3	6 ,,	,,
,, 4	4 ,,	,,
,, 5	3 ,,	,,

For measuring the mixture, spoons of various sizes are used, a spoonful of the largest being about 10 grs., whilst that of the smallest is only 1 gr. Generally a spoonful of the mixture is added to 5 English pounds of tea, so that the maximum quantity of the admixture amounts on 0,4%, corresponding to 0,001% of Prussian blue. For black tea, a small quantity of graphite is mixed, which imparts to the tea an uniform smooth and glossy appearance. Owing to the minute quantity of the admixture used for facing tea, some regard it as an admissible or even as a legitimate practice. Indeed, facing thus conducted is of no great consequence to public health, but this can not be taken as the ground for declaring the practice legitimate or even admissible. Facing and colouring ought to be most emphatically condemned not because of their injury to health, but because of their fraudulent intent. Various other kinds of adulteration, such as the addition of sand and clay, the admixture of foreign and exhausted leaves, etc. were formerly resorted to in this country, when the demand for tea exceeded the supply in consequence of the sudden opening of the trade with foreign countries. But owing to the gradual reduction of the price of tea, such adulterations take place at present but very rarely.

Thus, although nearly all export tea is more or less faced, that consumed at home is never dyed. But we have a number of plants the leaves of which are sometimes used as surrogates

for tea by our porest classes. The following table[1] shows the composition of some of these surrogates (per cent of dry matter):

JAPANESE NAME.	KUGOCHA.	UKOGICHA.	NINDOCHA.	AKEBICHA.	AMACHA.
Botanical name	Lycium sinense.	Acantho-panax spinosum	Lonicera flexuosa.	Akebia quinata	Hydrangea Thunhergii
Crude protein	35.72	21.26	20.33	27.42	23.93
Tannin	1.16	7.18	8.73	3.33	1.59
Ash	8.61	7.51	8.31	9.36	9.48
Soluble in hot water	27.15	43.94	43.00	37.42	33.33

To these might be added many more. It is clear that these surrogates cannot be successfully used for the purpose in view, since they are destitute of the active principle that addresses itself to the nervous system and gives tea its hold on the appetite of humanity. But some of them, as shown in the above table, contain more or less of tannin, so that the decoction made therefrom has an astringent taste, their wholesomeness upon the system depending chiefly on their being drunk hot.

Lastly with regard to the *preparation of green tea for the table*, different methods are adopted for different classes of tea. The principle should, however, be to extract the largest possible quantity of theine and a moderate amount of tannin, without dissipating much aroma. Now this object cannot be attained by boiling tea, nor by brewing it with cold water, but by subjecting it to the action of water of a certain temperature for a certain space of time, the latter two points being determined by the nature of the tea. The method employed, in this

1 Reproduced from O. Kellner's paper on "Zusammensetzung Japanischer landwirthschatfticher u. technischer Producte u. Materialien; Mittheilungen der deutchen Gesellschaft für Natur- u. Voelkerkunde Ostasiens, 1886, p. 205.

country, for making tea of an extra-fine quality, viz. *tencha*, is to grind the leaves to powder, which is drunk with the infusion. The second method used only for a superior tea, is to digest the leaves for about 2 minutes with warm water at a temperature of 50-60°C. The third one for a medium tea is to expose the leaves to the action of boiling water for about 1 minute. The last which is for used making an inferior tea is to boil the leaves with water. These methods of making tea are quite rational, since the finer the tea the higher is its solubility. In connection with this, it is interesting to know what constituents and how much of the latter are soluble in hot water J. M Eder[1] tried to determine what and how much of the constituents are soluble in water, and found in the case of Chinese tea the following figures.

	Dry matter.	Nitrogenous subst.	Theine.	Tea oil.	Resin, chlorophyll etc.	Tannin.	Extractive matter.	Ash.	Potosh	Lime	Phosphoric-acid.	Silica.
Dissolved by water.	40.00	12.0	2.0	0.6	—	10.0	12.0	1.7	09.38	0.036	0.133	0.021
Not dissolved by water.	60.00	12.7	0	0	7.2	—	11.0	2.3	0.290	0.584	1.031	0.680

Thus the three active constituents of tea—theine, tannin, and volatile oil—are completely dissolved by water, whilst only 40% of ash goes into solution, amongst which potash and phosphoric acid predominate. It is still a weighty and interesting matter to determine how much of the soluble constituents exudes into infusion by our methods of making tea for the table. O. Kellner[2] made, in conjunction with S. Ishii and M. Kamoshita, some researches on this subject. He digested, for this purpose, 90

1 König's Nahrungsmittel. II. vol., 2. edition, p. 619.

2 Mittheilungen der deutschen Gesellschaft für Natur- und Voelkerkunde Ostasiens, 1886, p. 212.

3 The price was 1½ Yen per Kin. 1 Kin=0.6 Kilogramm; 1 Yen=3—4 shillings.

grams of a superior green tea[3] with half a litre of distilled water at 50°C. After 5 minutes, the infusion was decanted off, and fresh water of the same temperature was added in equal proportion. This process was repeated three times, each infusion being analysed separately. From the results of these analyses I have calculated the following figures[1]:

	In 100 grs of tea employed	In 556 c.c of water used in each brewing.		
		First infusion.	Second infusion.	Third infusion.
Dry matter	88.60 grms.	4.69 grms.	4.17 grms.	3.16 grms.
Theine	3.43 ,,	0.50 ,,	0.41 ,,	0.42 ,,
Tannin	15.75 ,,	2.50 ,,	2.26 ,,	2.20 ,,
Total nitrogen	6.541 ,,	0.292 ,,	0.267 ,,	0.251 ,,
Ash	5.14 ,,	0.88 ,,	0.74 ,,	0.25 ,,
Ash ingredients:				
Potash	1.966 ,,	0.297 ,,	0.296 ,,	0.120 ,,
Soda	0.297 ,,	0.085 ,,	0.175 ,,	0.027 ,,
Lime	0.132 ,,	0.006 ,,	0.005 ,,	0.008 ,,
Magnesia	0.612 ,,	0.068 ,,	0.037 ,,	0.032 ,,
Ferric oxide	0.437 ,,	0.020 ,,	0.005 ,,	0.002 ,,
Mangano-maganic oxide	0.065 ,,	0.017 ,,	0.003 ,,	0.002 ,,
Phosphoric acid	0.921 ,,	0.065 ,,	0.036 ,,	0.028 ,,
Sulphuric acid	0.499 ,,	0.103 ,,	0.022 ,,	0.020 ,,
Silica	0.077 ,,	0.038 ,,	0.009 ,,	0.006 ,,
Chlorine	0.129 ,,	—	—	—

Hence of 100 parts of each tea-constituent, the following were found in the infusion:

1 As to the figures given in the following tables for *tannin* it should be kept in mind that the researches have been made by Loewenthal-Neubauer's method, before its revision and improvement by J. v. Schroeder. The contents of the tea and extract in tannin may have possibly turned out somewhat too high.

	First infusion.	Second infusion.	Third infusion.	Total.
Dry matter	5.3	4.7	3.6	13.6
Theine	14.6	12.0	12.3	38.9
Tannin..........	15.9	14.4	13.9	44.2
Total nitrogens ..	5.2	4.7	4.4	14.3
Ash	17.1	14.4	4.9	36.4
Ash ingredients:				
Potash	15.1	15.1	6.1	36.3
Soda	28.6	58.9	9.1	96.6
Lime	4.6	3.8	2.3	10.7
Magnesia........	11.1	6.0	5.2	22.3
Ferric oxide	4.6	0.1	0.05	4.75
Mangano-manganic oxide	26.2	4.6	3.1	33.9
Phosphoric acid ..	7.1	3.9	3.0	14.0
Sulphuric acid ..	20.8	4.4	4.0	29.1
Silica	49.4	11.9	8.1	69.4

Thus by this method of brewing tea (the warm water method) the first, second, and third infusions do not differ much in their contents of active ingredients. Indeed, daily experience teaches that the three infusions thus obtained have apparently the same flavour and body as it is termed. But the fourth infusion is usually defective both in aroma and body. In another method of making tea (the boiling water method) things are different. Here the first infusion contains far larger quantities of substances than the subsequent infusions. A trial by the same author[1] in which 100 grs. of tea also of a superior description[2] were digested for 2 minutes with 1 litre of boiling distilled water, gave the following results:

1 l. c. p. 212.

2 The tea here employed was more properly brewed by another warm water method, the price being 2 *Yen* per *Kin*.

In 100 grams of tea employed:		In the total infusion.	From 100 p. of each constituent the following parts were dissolved.
Dry matter	95.52 grms.	15.34 grms.	16.1 grms.
Theine	3.31 "	1.33 "	40.1 "
Tannin	19.10 "	7.04 "	36.8 "
Total nitrogen	6.19 "	1.061 "	17.1 "
Ash	5.92 "	2.14 "	36.1 "
Ash ingredients:			
Potash	3.195 "	1.384 "	43.8 "
Soda	0.307 "	0.101 "	32.1 "
Lime	0.572 "	0.034 "	6.0 "
Magnesia	0.359 "	0.142 "	39.4 "
Ferric oxide	0.204 "	0.022 "	10.8 "
Mangano-manganic oxide	0.098 "	0.050 "	51.0 "
Phosphoric acid	0.579 "	0.233 "	40.2 "
Sulphuric acid	0.326 "	0.080 "	24.5 "
Silica	0.186 "	0.004 "	2.1 "
Chlorine	0.127 "	0.069 "	54.3 "

Thus by this method, the first infusion contains soluble ingredients in quantities rather more than the sum of those contained in all the three infusions obtained by the other method. Here I must not forget to mention that the duration of brewing, the quantity and temperature of the water etc, in the above trials, nearly coincide with those practised in this country. Of course, the nature of the water used for brewing tea may have a slight influence upon the infusion; in practice soft water is preferred to hard water.

It might be interesting to cast a glance upon the concentration of the beverage as prepared by the two above methods. There was contained in one litre of the infusion:

By the warm water method.	Dry matter.	Theine.	Tannin.	Crude protein.	N-free extract.	Total ash.	Potash
1st infusion......	8.43	0.91	4.49	0.528	1.82	1.59	0.535
2nd ,, ...	7.60	0.74	4.07	0.476	1.83	1.33	0.533
3rd ,, ...	5.69	0.75	3.97	0.452	0.82	0.45	0.216
average	7.24	0.80	4.18	0.486	1.29	1.29	0.428
By the boiling water method.	15.34	1.33	7.04	1.061	5.08	2.11	1.384

The latter numbers are too high, since in the above trial, a superior tea was employed, while in practice only a medium sort is brewed in this way. Assuming that we drink daily 300 c. c. of such iufusion, as prepared by the warm water method, we shall consume the following quantities of the active components of tea (in grams):

Dry matter.	Theine.	Tannin.	Crude protein.	N-free extract.	Total.	Potash
2.17	0.24	1.25	0.15	0.39	0.34	0.13

The tea used by the middle classes is of a description far inferior to that above mentioned, being generally about 20-30 *sen* per *kin*. An analysis of such tea, made in our laboratory, gave the following results.

Water..................11.45%

In 100 parts of dry matter:		In 100 parts of pure ash:	
Crude protein.	26.87	Potash.	36.93
Crude fibre.	10.89	Soda.	9.78
Ethereal extract.	15.64	Lime.	3.24
Other nitrogen-free extract.	22.92	Magnesia.	12.56
Ash.	6.23	Ferric oxide.	8.92
Theine.	2.03	Mangano-manganic oxide.	1.01
Tannin.	17.65	Phosphoric acid.	15.72
Soluble in hot water.	38.89	Sulphuric acid.	7.46
Total nitrogen.	4.299	Silica.	1.57
Non-albuminous nitrogen.	0.955	Chlorine.	2.21

For brewing such tea, generally, a decoction method is applied. Assuming that we consume daily 15 grams of air dry tea, and that the whole of the theine and tannin is dissolved by water,

while 50 % of crude protein, 40 % of total ash, and 80 % of potasium salt can be got in the decotion, we find that the following quantities of these constituents are partaken of by one person (in grams):

Dry matter.	Theine.	Tannin.	Crude protein.	Total ash.	Potash.
5.16	0.27	2.17	0.18	0.39	0.24

The same quantity, namely 15 grams of air-dry coffee, which may be assumed to be daily partaken of by one person, contain according to J. König[1] the following quantities of soluble substances (in grams):

Total soluble.	Caffeine.	Oil.	Nitrogenfree extractive, Matter.	Ash.	Potash.
3.82	0,26	2.17	2.17	0.61	0.36

Hence we may assume that on an average the quantity of theine daily consumed by one adult person is nearly equal, namely about 0.26 grams.

1 König's Nahrungsmittel. Vol. II, p. 606. 2. edition.

Researches on the Nitrogenous Non-Albuminous Constituents of Bamboo Shoots.

BY

Y. Kozai.

Since O. Kellner[1] discovered the fact that all green plants normally contain nitrogenous non-albuminous substances in considerable proportions, and since J. Borodin[2] published his well-known memoir "Über die physiologische Rolle und die Verbreitung des Asparagins im Pflanzenreiche," the study of nitrogenous non-albuminous constituents of plants has received special attention among distinguished German authors, among whom E. Schulze is prominent. Indeed, the fact that albuminoids undergo a far reaching change in the organism of plants has been brought to light, since Pfeffer confirmed and extended the observation of Th. Hartig on the presence of asparagine in the vegetable kingdom. It was, however, soon discovered by the researches of E. Schulze and J. Barbieri[3] on pumpkin sprouts, that asparagine is not the sole product of the decomposition of albuminoids in vegetable bodies, but that there occur many other substances of an analogous nature known to have been produced from albuminoids, since they found in the sprouts, besides asparagine and glutamine, also tyrosine and leucine. The same fact may also be induced from the

---

1 Landwirthschaftliche Jahrbücher, 1879, 1. Supplement, p. 243.

2 Botanische Zeitung, 1878, p. 802.

3 Landwirthschaftliche Jahrbücher, Vol. VI, p. 681.

the researches of v. Gorup-Besanez[1] who detected, besides asparagine, also leucine, glutamine, and tyrosine in vetches grown in the dark, the presence of leucine in the same plants having been confirmed by A. Cossa.[2] Moreover, E. Schulze and J. Barbieri detected tyrosine and leucine in potatoes,[3] isolated amidovaleric acid and phenylamidopropionic acid from the shoots of Lupinus luteus[4], the latter compound occurring also in the young plants of Soja hispida,[5] and separated allantoin in the shoots of Platanus orientalis[6]. Furthermore the same author and E. Bosshard[7] found allantoin in the young buds of Acer pseudoplatanus, and Acer campestre, and also in the bark of Aesculus hippocastanum, and Acer pseudoplatanus; they[8] discovered vernin in the young plants of Vicia sativa und Trifolium pratense. Again in combination with J. Hungerbühler he found vernin in Secale cornutum[9], with E. Steiger and E. Bosshard in Medicago sativa[10], and in conjunction with A. von Planta, in the pollens of Coryllus avellana and Pinus sylvestris[11]. Finally, the same author and E. Steiger[12] discovered arginin in etiolated lupine and pumpkin shoots. Besides these, the author found cholin in the etiolated seedlings of yellow lupines, pumpkin[13], and soy bean[14]. In short, we are chiefly indebted to E. Schulze and his assistants, for the en-

---

1 Berichte der Deutschen chemischen Gesellschaft. Vol. VII, p. 146 and 569; Vol. X, p. 780.

2 Gazetta Chimica Italiana. VI, p. 314.

3 Landwirthschaftliche Versuchs-Stationen. Vol. XXIV, p. 167.

4 Landw. Jahrbücher. Vol. XII, p. 910.

5 Zeitschrift für physiologische Chemie, Vol. XII, p. 405.

6 Bericht der Deutschen chemischen Gesellschaft, Vol. XIII, p. 1602.

7 Zeitschrift für physiologische Chemie. Vol. 9, p. 420.

8 ,, ,, ,, ,, ,, 10, p. 80.

9 ,, ,, ,, ,, ,, 10, p. 83.

10 Landwirthschaftliche Versuchs-Stationen. Vol. 33, p. 105.

11 Zeitschrift für physiologische Chemie, Vol. 10, p. 326.

12 ,, ,, ,, ,, ,, 11, p. 43.

13 ,, ,, ,, ,, ,, 11, p. 365.

14 ,, ,, ,, ,, ,, 12, p. 405.

unciation of reliable methods of eliminating these substances, and through their labours, knowledge of the metamorphism of albuminoids in the vegetable organism has been much increased.

As regards the presence of bodies of xanthine- and hypoxanthine-groups[1] in plants, G. Salomon[2] found hypoxanthine and probably also xanthine in lupine shoots, a fact afterwards confirmed by E. Schulze and J. Barbieri;[3] Reinke and Rodewald[4] detected hypoxanthine and guanine in the protoplasm of Aethalium septicum, Schützenberger[5] found the same substances in self-fermented yeast; Baginsky[6] detected hypoxanthine and xanthine in Chinese black tea; I found hypoxanthine, xanthine and also guanine in fresh tea leaves[7]; E. Schulze and E. Bosshard[8] found hypoxanthine, guanine, and also, in many cases, xanthine in a great many young plants, either grown in light or kept in the dark; E. Schulze, E. Steiger, and E. Bosshard[9] found the bodies of xanthine and hypoxanthine groups in Vicia sativa, Trifolium pratense, Medicago sativa, Avena sativa and Lolium italicum; finally A. Kossel[10] discovered adenin in the alcoholic extract of tea. It is, however, A. Kossel to whom is reserved the honour of bringing forward, by a series of brilliant researches[11] an in-

1 The terms suggested by E. Schulze (Zeitschrift für physiologische Chemie, Vol. 12. p. 405) for designating xanthine and guanine, on one side, and hypoxanthine and adenin on the other.

2 Jahrbericht der Chemie, 1881, p. 1012. Salomon also detected these bodies in the germs of malt.

3 Journal für practische Chemie, Vol. 37, p. 358.

4 Untersuchungen aus dem botanische Laboratorium in Göttingen, Vol. II. p. 147.

5 Jahrbericht der Chemie, 1874. p. 952.

6 Zeitschrift für physiologische Chemie, Vol. 8, p. 395.

7 A full detail will be published in these Bulletins.

8 Landw. Vers. Stat. Vol. 33, p. 89.

9 Zeitschrift für physiologische Chemie, Vol. 10, p. 262.

11 Zeitschrift für physiologische Chemie, Vol. V, p. 152 and 167; Vol. VI. p. 422; Vol. VII, p. 7; Vol. VIII,. p. 404; Vol. X, p. 248.

teresting fact on the intimate connection of these bases and nucleine, and thus throwing a new light on the chemistry of plants and animals.

As among the plants or parts of plants in which crystallizable nitrogenous substances have been hitherto searched for in a detailed way, gramineae are almost absent, it appeared to be interesting, to study from this point of view a member of that large family, which calls forth our admiration every spring, on account of the enormous size of its shoots as well as the rapidity of their growth. *Bamboo shoots*, a favourite article of food in our country, are indeed very rich in nitrogenous non-albuminous substances; an analysis made of the edible part of the largest variety in our laboratory showed that nearly 70% of total nitrogen exists in the form of non-albuminous substances. Its per-centage composition was found to be as follows:

Water	91.37.
In 100 parts of dry substance:	
Crude protein	25.12.
Crude fat.	2.49.
Crude fibre	11.60.
Nitrogen-free extract	41.52.
Ash, free from CO_2	9.22.
Total nitrogen	4.04.
Nitrogen in amides, etc	2.82.

The method I adopted in the investigation undertaken was exactly the same as that recommended by E. Schulze and may be briefly stated as follows: 50 kilograms of fresh bamboo shoots, freed from bark and cut into thin slices, were thoroughly extracted with boiling water, and the extract was treated with basic lead acetate. The filtrate from the lead compounds was treated with an excess of mercuric nitrate, when a large quantity of a faint coloured precipitate was formed, which was much enhanced by the addition of a little caustic soda. After

allowing it to stand for 12 hours, the precipitate was separated by filtration, thoroughly washed with cold water, suspended in a large quantity of water, and decomposed by a stream of hydrogen sulphide. The filtrate being then neutralized with a little ammonia, was slowly evaporated over a water bath, during which time a little ammonia was added from time to time, to maintain the neutrality of the evaporating fluid. When the whole filtrate was concentrated into about half a litre, a white crystalline substance appeared on the surface of the fluid, rapidly increasing in quantity until after a short time, the whole surface was covered with a crystalline crust. Upon cooling, so many crystals were separated that the whole became a semi-fluid mass. The crystals thus obtained were collected upon a filter, thoroughly washed with cold water, then with absolute alcohol, and finally with ether, again dissolved in the smallest possible quantity of boiling water, and allowed to recrystallize by slow cooling. This alternate dissolution and crystallization was repeated until the crystals became completely white, and left no ash upon ignition. This substance when crystallized from the aqueous solution formed long entangled slender needles with a brilliant silky lustre, but crystallized out in tufts of larger needles also with a silky lustre from an ammoniacal solution. It was insoluble in ether, sparingly soluble in cold water and in alcohol, moderately soluble in hot water, and easily so in caustic alkalies, ammonia, and mineral acids. When burnt, it produced a peculiar smell resembling that of burning horn or hair. It gave the sharp reactions of Piria's[1], Scherer's[2] and L. Meyer's[3] tyrosine tests, and formed small deep blue needles with cupric hydroxide[4]. It did not give Kreitmayer's[5] rathanine-reaction. The determination of the nitrogen of the substance by Kjeldahl's method gave the following result:

1, 2, 3. Neubauer, Harn-Analyse, 1876, p. 116.

4 Beilstein, Organ. Chemie, Vol. II. 2. edition, p. 1007.

5 ,, ,, ,, , Vol. III. 2. edition, p. 283.

0,357 gram. of the substance, dried at 110°C.
gave 0,0281957 gr. N. in the form of ammonia.

Calculated for $C_9H_{11}NO_3$.	Actually found.
N 7·73°/₀.	7·90°/₀.

The slightly high percentage of nitrogen actually found might perhaps be attributed to a slight admixture of leucine which is constanly found associated with tyrosine. The substance in question was, beyond any doubt, *tyrosine.* The total quantity of tyrosine obtained amounted to about 2,5 grams; hence the quantity actually contained in the material under examination must have been far greater, since not only a part of the substance would remain undissolved, but also some would be retained in the lead compounds, whilst another, perhaps, still greater part might have escaped the precipitation by mercuric nitrate.

The filtrate from tyrosine crystals yielded, upon further concentration, a second crop of impure tyrosine. The concentrated solution was then allowed to slowly evaporate over sulphuric acid. After a few days, large shining transparent prismatic crystals were formed, amounting to about 1 gram. Their characteristic crystalline form, *a priori*, pointed out that the crystals were *asparagine.* The aqueous solution not only threw down the characteristic copper compound when boiled with freshly precipitated cupric hydroxide and allowed to cool, but also disengaged ammonia gas when boiled with caustic potash. The determination of "water of crystallization" in the crystals specially purified, gave the following result:

0.200 grms. of the crystals lost 0,02392 gr.
at 105°C.

	Calculated for $C_4H_8N_2O_3+H_2O$	Actually found
H_2O	12.00°/₀	11.96°/₀.

The liquor separated from asparagine crystals served for the examination of xanthine and hypoxanthine bodies. For this purpose, the solution, after having been diluted with twice its own volume of water, was treated with an ammoniacal

silver nitrate solution, which was added in slight excess, when a large quantity of a dark coloured precipitate was formed. The precipitate thus obtained, was collected upon filtering paper, washed with a dilute ammoniacal silver nitrate solution, and afterwards with cold water. It was then dissolved in hot dilute nitric acid of the specific gravity 1.10 (after the addition of a little urea), and the solution was allowed to cool, when a large quantity of a beautiful white crystalline substance was separated. After 24 hours' standing, the precipitate was separated by filtration, washed with cold water, and suspended in hot water slightly acidified with hydrochloric acid, through which a stream of hydrogen sulphide was passed. The filtrate from silver sulphide being then neutralized by ammonia, was evaporated to dryness. The residue was repeatedly extracted with dilute ammonia, in which it was almost completely dissolved, leaving behind a small quantity of a yellowish powder. This latter substance amounting to about 1.5 centigrams was found to be quite insoluble in water, alcohol, ether, and dilute ammonia, soluble in dilute acids and caustic alkalies, and sparingly so in boiling strong ammonia from which it was again thrown down in a crystalline form when cooled and left to stand.[1] This powder not only gave the well known Capranica's guanine reaction[2] but also produced the characteristic change of colour when treated with nitric acid and caustic soda.[3] Hence there could be no doubt that this powder was *guanine*.

The ammoniacal solution from which guanine had separated, was again treated with ammoniacal silver nitrate solution, the precipitate thus obtained was, after thorough washing with cold water, again dissolved in hot nitric acid of the said specific gravity, with the addition of some urea crystals, and the solution

1 The property found by Drechsel, See Journal für practische Chemie, [2], Vol. 24, p. 44.

2 Zeitschrift für physiologsiche Chemie, Vol. 4, p. 233.

3 Hoppe-Seyler, Handbuch der physiologisch- und pathologisch-chemischen Analyse, 5th edition, p. 151.

was allowed to cool, when a beautiful white crystalline precipitate was formed, which was immediately separated by filtration. For further purification, the crystals were once more dissolved in the said reagent and allowed to recrystallize. The purified substance formed, when viewed under the microscope, long colourless needles not blackened by exposure to light and bearing the closest resemblance to hypoxanthine silver nitrate prepared form the pure substance. The purified silver compound was digested in ammonia in which a little silver nitrate was dissolved, then filtered, washed with cold water, suspended in hot water, and decomposed by hydrogen sulphide. The filtrate from silver sulphide was evaporated to dryness, when a faintly coloured crystalline powder was left behind. This substance, when evaporated with nitric acid, left a slightly yellowish residue, which dissolved in caustic potash without any colouration. It produced a faint rose-red colour when treated with chlorine water and ammonia gas.[1] According to A. Kossel,[2] Weidel's colour-reaction does not properly belong to hypoxanthine but to xanthine, these two substances being most generally found in company. The same author[3] also found that adenin gives the same colour reaction as xanthine. Hence the substance in view might have contained, in spite of repeated recrystallization, a minute quantity of xanthine or adenin, but it is quite certain that it was *hypoxanthine.*

The nitric acid solution from which hypoxanthine and guannine-silver compounds were separated threw down, after a few days, a pretty large quantity of a white crystalline precipitate. An addition of ammonia in slight excess to this solution produced a large qnantity of a flocculent slightly yellowish precipitate. The precipitate was separated by filtration, washed with cold water, suspended in hot water, and finally decomposed by hydrogen sulphide. The filtrate from silver sulphide,

---

1 Fresenius, Zeitschrift für analytische Chemie, 1872, p. 96.

2 Zeitschrift für physiologische Chemie, Vol, 6, p. 426.

3 ,, ,, ,, ,, ,, 10, p. 255.

left, upon evaporation, a slightly yellowish powder. This residue was found to be slightly soluble in water, and easily so in ammonia, from which it separated in a crystalline form when the solvent passed away. It not only gave Weidel's colour-reaction, but also Hoppe-Seyelrs'[1] as well as Scherer-Kerner's[2] xanthine-reactions. Hence, the residue consisted of *xanthine*.

Furthermore, I found that an alcoholic extract of dried bamboo shoots produced, upon standing, a pretty large quantity of fine crystals, which were found to produce oxalic acid and ammonia when boiled with caustic potash. The study of the nature of these crystals, which very likely will prove to be *allantoin*, will be deferred to future investigations.

The chief interest attached to the investigation undertaken, is the finding of a pretty large quantity of tyrosine contained in bamboo shoots, since it is the first time, so far as my knowledge goes, that so much of it has been isolated from a plant belonging to gramineæ.

The xanthine and hypoxanthine bodies above described might perhaps be partly formed from nucleine during the extraction of the material, since A. Kossel[3] found that nucleine undergoes a partial decomposition even when simply heated with water. Whether or not this is so, the result of the investigation may be looked upon as giving further support to A. Kossel's assumption that xanthine and hypoxanthine bodies either pre-formed or in a combined state in nucleine, are widely distributed in the organisms of animals and plants. It verifies, at the same time, E. Schulze's[4] recommendation of the application of mercuric nitrate for the investigation of the regressive products of albuminoids in plants.

---

1 Hoppe-Seyler, Handbuch der physiologisch- u. pathologisch-chemischen Analyse, 5th edition, p. 148.

2 Neubauer, Harn-Analyse. 1876, p. 25.

3 Zeitschrift für physiologische Chemie. Vol. III, p. 291; Vol, IV. p. 290; Vol. VI p. 152.

4 Ibid. 9, p. 443.

I must here express my hearty thanks to Dr. O. Kellner, the director of our laboratory, under whose control, I performed this and former researches, and who has not only put the necessary literature at my disposal, but has also overlooked and revised these papers.

東京農林學校
學術報告
第八號

Imperial College

OF

AGRICULTURE AND DENDROLOGY.

KOMABA, TOKYO, JAPAN,

BULLETIN NO. 8.

Manuring Experiments with Paddy Rice.

(With 4 Plates.)

Communicated

BY

DR. O. KELLNER,
Professor of Agricultural Chemistry

明治二十三年六月
TŌKYŌ, JAPAN, JUNE, 1890.

PRINTED BY HAKUBUNSHA, GINZA, TŌKYŌ

Manuring Experiments with Paddy Rice.

BY

Dr. O. Kellner, Y. Kozai, Y. Mori and M. Nagaoka.

It is a well established fact that of the nutrients required by crops some exist in the soils and ordinary manures in sufficient quantities, and need not be specially cared for in farming, while others are less copious and must be carefully taken into account in the application of manures. These latter nutrients are: *nitrogen*, *phosphoric acid*, *potash*, and sometimes, though rarely, *lime*. Manuring experiments, which tend to reveal the needs of a soil or crop, have accordingly to deal chiefly with these four nutrients and to ascertain what *quantity and form* of each is the most suitable and economical under given conditions.

In making researches of this kind the so-called "law of the minimum factor" plays an important part. According to it, the material produce by crops depends upon that essential factor of production which is least available to the crops. For instance, if a soil is well supplied with nitrogen and potash and all other conditions are favorable to a normal produce, but if at the same time phosphoric acid is available only in a small proportion, the yield of the crop will be determined by this latter nutrient; if only water is deficient in the soil, the yield depends on this factor of growth, etc. Hence, if we wish to find out whether any, and if so, how much of a certain nutrient is to be applied to a certain soil and crop, we have to arrange a series of experimental plots and to supply them with so much

of each nutrient and factor of production as will amply suffice for a maximum yield, excepting, however, the nutrient under experiment which must be applied in different doses. If the soil is originally poor in this nutrient, the yield will be, up to a certain limit, proportional to the amount of the nutrient given; and on the other side, if it be *a priori* rich in it, the yield will not be much influenced by different doses of that nutrient. The upper limit to which the yield can be economically increased, gives a reliable measure for the quantity of the nutrient to be applied in practice.

Among the important vegetable nutrients, nitrogen and phosphoric acid exist in the manures in very *different forms*, some of which can be directly consumed by the plants, and consequently have a speedy effect on the crop; while others must be decomposed in the soil before plants can take up their nutritive ingredients, which circumstance may retard and diminish the effect.[1] Comparative trials with various forms of nutrients accordingly constitute also an essential object of agricultural experimental work and are just as necessary as researches on the quantities of *available* nutrients needed for a maximum yield of a special crop.

Manuring experiments which are to decide upon subjects of *general* importance, cannot be well carried out on large plots, because of the frequent inequalities of the soil and difficulties of making the general factors of production quite equal on all plots. Small patches, on the other hand, admit of easy and accurate management and allow of constant control over all the factors that influence the development of plants. The only draw-back to trials on a small scale is that they are in a more favourable condition of light and heat than large plots, but in many cases this source of error can be avoided by surrounding the small plots with the same kind of plants, so as to confer on all trials the conditions of a single large field.

On the principles explained in the preceding lines, and

---

1 See Bulletin No. 6, p. 25.

first applied with excellent success by P. Wagner, we carried out in the summer of 1889 a series of manuring experiments with paddy rice, for the purpose of determining what quantities of assimilable nutrients are needed by this crop under the conditions of the soil in our neighbourhood, reserving the researches on the availability of various forms of nitrogenous and phosphatic fertilizers till next year.

The soil of the experimental field chiefly consists of volcanic ashes, and resembles in its physical properties a sandy loam. It has a good capacity for imbibing and conducting water, and swells up a little when copiously moistened, but does not exhibit any considerable plastic condition; hence its surface, in times of scanty rain, forms to a depth of 1—2 inches a dry porous light mass liable to be blown about by the wind. Its chemical condition is illustrated by an analysis made in conjunction with *H. Imai* in 1882.[2]

The air-dry soil contained:

	Topsoil.	Subsoil.
Hygroscopic water	14.30 %	12.84 %
Loss on ignition...	22.30 ,,	18.79 ,,
Humus...	9.96 ,,	8.86 ,,
Nitrogen	0.489 ,,	0.799 ,,
Combined water...	11.85 ,,	9.13 ,,

In 100 parts of soil free from water there was found:[3]

2 Landw. Versuchsstationen, vol. 30, 1883, p. 1.

3 This analysis was made in the usual way; the remainder left after the extraction with hot hydrochloric acid was treated with concentrated sulphuric acid, and the substance insoluble in the latter reagent was dissolved in hydrofluoric acid.

	Extracted by hot hydrochloric acid of the spec. gravity 1. 15		Extracted by hot concentrated sulphuric acid.		By treatment with hydrofluoric acid.	
	Top soil.	Sub-soil.	Top soil.	Sub-soil.	Top soil.	Sub-soil.
Silica[4]	18.60	15.58	1.41	1.55	17.42	22.45
Alumina..	17.05	14.80	0.70	0.88	3.01	3.06
Ferric oxide	3.95	2.68	0.40	0.35	1.40	1.87
Ferrous ,, ...	4.71	5.31	—	—	—	—
Lime	0.90	0.80	0.31	0.10	0.94	1.01
Magnesia	0.66	0.62	0.12	0.10	0.70	0.79
Potash	0.32	0.26	0.09	0.13	0.33	0.45
Soda	0.19	0.25	0.12	0.16	0.33	0.50
Phosphoric acid	0.49	0.40	—	—	—	—
Sulphuric ,, ...	0.16	0.08	—	—	—	—
Chlorine..	0.03	0.03	—	—	—	—
Total	47.06	40.81	2.97	3.27	24.13	30.13
Undissolved, resp. undecomposed mineral matter ..	27.10	33.40	24.13	30.13	—	—

Our soil is accordingly rich in humus, compounds of iron, and easily decomposable silicates, but very poor in clay (hydrous silicate of alumina). Its considerable content of organic matter, the low situation as a paddy field and the presence of much moisture throughout the year render it inclined to sourness and cause a considerable reduction of the sesquioxide of iron to protoxide. As to its deportment toward nutritive solutions our researches show that ammonia, and consequently also potash, are very strongly absorbed, the coefficients of absorption determined by Knop's method were 99 for the topsoil and 90 for the subsoil; phosphoric acid is retained to a still far higher rate. Hence ammoniacal and potassic salts, as well

4 Including the silica dissolved by a solution of sodium carbonate, after the treatment with hydrochloric resp. sulphuric acid.

as soluble phosphates when applied as manures are not liable to be extracted in noticeable quantities by the usual irrigation.

The water used far the irrigation of our experimental plots came from a spring situated about 500 metres from the field, and was guided through a ditch into a reservoir near the plots. It did not supply our plants with any remarkable amaunt of nutrients, as it is of exceptional purity. Analyses of this water before and after it had passed over a plot of about 400 square metres, made in 1882 in conjunction with *J. Sawano*, have shown[5] that it contains in 100 litres in grammes :

	Influent water.	Effluent water.	Difference.
Total dry matter	4.500	3.900	−0.600
Silica..	1.291	1.343	+0.052
Alumina, Ferrous and Ferric oxide	0.666	0.355	−0.311
Lime..	0.782	0.273	+0.091
Magnesia..	0.493	0.370	−0.123
Potash and Soda (as chlorides)	1.103	1.016	−0.087
Phosphoric acid	0	0	—
Sulphuric acid..	0.054	0.059	+0.005
Chlorine	0.088	0.113	+0.025
Nitric acid	0.887	0.430	−0.457
Ammonia..	0.063	0.076	+0.013

These figures do not, of course, exactly indicate how much of each ingredient is actually retained by the soil or assimilated by the plants, because the quantity of the water while it is slowly running over the field, is diminished by evaporation or increased by rain, which processes certainly do not quite compensate one another. The difference between the incoming and exit waters is, however, so trifling that in our case manuring experiments are not disturbed by the minute quantities of vegetable nutrients supplied or withdrawn by the water of irrigation.

The experiments were carried out in square frames which we have successfully used on dry land since 1885. Each frame surrounding an area of 9 square *shaku* (=0.82645 square

5 Landw. Versuchsstationen, 1883, vol. 30, p. 39.

metres), was sunk several feet from its neighbour 1.5 foot into the soil projecting about 2 inches above the surface. As each plot had to be supplied with water that had not yet been used for the irrigation of others, a tub was placed on a small support on the northern side of each frame and furnished with a spout with a small opening through which the water was let in. A small notch in the side of the frame served as the outlet for waste water, but an overflow took place only rarely, in times of copious rain, because usually the surrounding not irrigated area absorbed moisture sufficient to allow of keeping up a normal irrigation without much overflow. The temperature of the water in the tubs was, of course, a little higher than in the channels from which paddy fields are commonly supplied, but the difference between the water in the frames and that on adjoining ordinary rice fields amounted, according to several observations during July and August, in maximo only to about 1°C. Our contrivance had, however, this disadvantage that the plants of the small patches not being surrounded by other plants were in a somewhat better condition as to the supply of solar light than rice on large areas. The whole experimental field had been ploughed and converted into a swamp in the preceding March, all lumps being crushed, the soil well mixed and levelled, whereupon the frames were sunk in.

As the *purpose of the experiment* was to determine how much assimilable nitrogen, phosphoric acid, potash, and lime are requisite for the production of a maximum rice crop, all fertilizers were given in the most soluble form, viz the nitrogen as ammonium sulphate, the phosphoric acid as ordinary sodium phosphate, the potash as carbonate and the lime in the slaked condition. Besides this, one special series was established with regard to the effect of green manure as a nitrogenous fertilizer. In several districts of Japan the farmers sow in September or October between the rice a leguminous plant called "*genge*" (Astragalus lotoides) which attains in the next year the flowering stage before the rice is transplanted. At that time the whole *genge* crop is incorporated in the field on which

it had been raised. This practice, which deserves to be as widely extended as possible throughout the rice growing districts, obviously aims at an accumulation of nitrogen in the soil and thus at a reduction of nitrogenous manures. It is a recently well established fact that leguminous plants have the peculiar faculty of assimilating the free nitrogen from the air, which process is not accomplished in other kinds of plants. Thus, by the cultivation of *genge* and other leguminous crops and by using them as manure on the same land, the farmer increases the stock of nitrogen in the soil. We sowed these plants on 12 plots on April 4th after applying 3 days previously phosphoric acid and potash, and to 9 plots among the 12 also lime. When however the time came for planting the rice, the genge was still very small and could not yet have accumulated much nitrogen, wherefore these trials will be repeated in the coming season (1890). The quantities of nutrients applied per *tan* ($=^1/_{10}$ hectare) were the following:

I. Series. Unmanured, and Partial Manures.

Plot 8, 32 and 61	Unmanured.
„ 9, 33 and 62	25 kilogrms. phosphoric acid and 20 kilogrms. potash.
„ 10, 34 and 63	25 kilogrms. phosphoric acid and 15 kilogrms. nitrogen.
„ 11, 35 and 64	20 kilogrms. potash and 15 kilogrms. nitrogen.
„ 12, 36 and 65	Unmanured.

II. Series. Nitrogen.

General Manure for each plot: 25 kilogrms. phosphoric acid and 20 kilogrms. potash.

Plot 1, 13, and 20	5	kilogrms.	nitrogen
„ 2, 14 and 21	7.5	„	„
„ 3, 15 and 22	10	„	„
„ 4, 16 and 23	12.5	„	„
„ 5, 17 and 24	15	„	„
„ 6, 18 and 25	17.5	„	„

III. Series. Phosphoric Acid.

General Manure for each plot: 15 kilogrms. nitrogen and 20 kilogrms potash.

Plot 27, 37 and 42	5 kilogrms. phosphoric acid.
,, 28, 38 and 43	10 ,, ,, ,,
,, 29, 39 and 44	15 ,, ,, ,,
,, 30, 40 and 45	20 ,, ,, ,,
,, 5, 17 and 24	25 ,, ,, ,,
,, 31, 41 and 46	30 ,, ,, ,,

IV. Series. Potash.

General Manure for each plot: 15 kilogrms. nitrogen and 25 kilogrms. phosphoric acid.

Plot 47, 57 and 72	5 kilogrms. potash.
,, 48, 58 and 73	10 ,, ,,
,, 49, 59 and 74	15 ,, ,,
,, 5, 17 and 24	20 ,, ,,
,, 50, 60 and 75	25 ,, ,.

V. Series. Lime.

General Manure for each plot: 15 kilogrms. nitrogen, 25 kilogrms. phosphoric acid and 20 kilogrms. potash.

Plot 5, 17 and 24	No lime
,, 54, 68, and 77	20 kilogrms. lime
,, 55, 69, and 78	40 ,, ,,

VI. Series. Green Manure and Lime.

General Manure for each plot: 25 kilogrms. phosphoric acid and 20 kilogrms. potash.

Plot 7, 19 and 26	Green Manure, no lime.
,, 57, 56 and 70	,, ,, and 20 kilogrms. lime
,, 52, 66 and 71	,, ,, 30 ,, ,,
,, 53, 67 and 76	,, ,, 40 ,, ,,

Before the application of the manures the whole soil of each plot was again converted, by the addition of water and stirring, into a fine mud entirely saturated with water to a depth of

about 40 centimetres. On March 31st, the slaked lime was incorporated, 2 days afterwards on all plots of the 6th series the sodium phosphate and potassium carbonate, and again after 2 days the *genge* was sown. On the other plots the sodium phosphate and potassium carbonate were spread and harrowed in on June 22nd, and after an interval of 4 days, during which the latter manures had been absorbed, the ammonium sulphate was incorporated with the muddy soil.

The plants for the experiments had been raised in seed beds in the usual way and were transplanted into the plots on June 29th, when they were about 5 inches high. Each plot received 16 bundles of healthy uniform plants, in all 240 plants. The variety used, known as *Satsuma* rice has a medium length of vegetation and is distinguished by the production of much grain in proportion to the straw, but the size of the grain is not large. Irrigation was at once commenced after transplantation. The treatment during the growth was just the same as is customary in our neighbourhood.

Already a fortnight after transplantation the different manures manifested distinct effects. The unmanured plants remained small and became pale, the *genge* plants were a little more greenish, while all others appeared at that time vigorous and healthy. In the course of time the unmanured plots also acquired a dark green colour, but all those plants which had received besides phosphoric acid less than 10 kilograms of nitrogen per tan as well as those with green manure became light green, and ripened about 12 days earlier than on the other plots. Those with no phosphoric acid did not exhibit the least difference from the unmanured plots during the whole season, and ripened also late.

During the time of flowering, which commenced on August 27th and was at its height on Septenber 1st-8th, the weather was rather unfavourable, rainy, and cold; and the terrific hurricane that blew over the country on the night of the 11th-12th of Septenber did considerable damage. Many of the panicles dried up in consequence of the injuries done by that

storm, but only a few stems were broken. A fortnight after the storm we collected the dried panicles from all plots in order to avoid losing them by the wind, and to get a reliable basis for correcting the damage sustained by the storm. After all, *the summer of* 1889 *was exceptionally unfavourable to the rice crop*, especially to the medium and late varieties, which suffered from the hurricane just in their most sensible phase of development. Official returns give the loss caused by the storm to 20-30%, in some districts to 40 % of the general average yield.

On the 6th and 7th of November the rice was cut. In each plot a bundle was selected before cutting, representing the medium condition of the crop, and from the 3 parallel plots of each trial that bundle which again appeared to be the medium of the three was taken out. The 4 plates annexed to this report are faithful reproductions of these photographs and will afford a good illustration of the effects of the different manures.

After the crops had become uniformly dry, the straw, full grain, and empty hulls were weighed, the full grain was hulled on a small machine and the weights of the hulled grain and hulls separately determined. Afterwards we ascertained the weight of 1000 hulled grains and 1000 undeveloped hulls damaged by the storm, an got thus the data requisite for a calculation of the total yield of hulled grain which would have been obtained if in each empty hull a normal, grain had developed. In the following pages the figures obtained in the latter way are quoted as "corrected yield" of grain.

A detailed record of the results obtained on each plot will be found in the appendix. The following table contains the averages from the parallel trials :—

Special Manures, per tan.	Yield per plot. Straw. grms.	Full grain. grms.	Empty grain. grms.	1000 full unhulled grains weigh grms.	100 parts of full grain yield Hulled grain. °/o	Chaff. °/o	Number of Panicles per plot.
I. Unmanured, and Partial Manures.							
Unmanured	197	106.4	6.5	26.88	81.82	17.82	237
Without Phosphoric acid	193	89.7	6.5	25.70	81.80	17.67	243
,, Nitrogen	459	367.3	15.3	27.42	82.80	16.99	267
,, Potash	714	564.0	23.8	26.80	82.08	17.39	396
II. Nitrogen.							
Without Nitrogen	459	367.3	15.3	27.42	82.80	16.99	267
5 Kilogrms. Nitrogen	664	475.0	24.2	26.92	82.00	17.37	319
7.5 ,, ,,	738	527.1	31.3	27.19	82.60	17.02	361
10 ,, ,,	830	569.4	21.7	25.73	81.52	17.57	393
12.5 ,, ,,	820	575.4	23.9	26.32	82.28	17.46	390
15 ,, ,,	832	575.1	31.1	26.75	81.40	18.04	393
17.5 ,, ,,	868	574.8	38.3	25.85	82.00	17.48	412
III. Phosphoric Acid.							
Without phosphoric acid.	193	89.7	6.5	25.70	81.80	17.67	243
5 Kilogrms. ,, ,,	417	281.5	14.5	27.86	82.24	17.13	277
10 ,, ,, ,,	616	485.4	23.1	27.46	82.60	16.64	343
15 ,, ,, ,,	762	584.0	25.3	27.51	82.04	17.56	373
20 ,, ,, ,,	843	635.7	28.7	26.70	81.64	17.74	393
25 ,, ,, ,,	832	575.1	31.1	26.75	81.40	18.04	393
30 ,, ,, ,,	951	647.4	33.7	26.30	82.04	17.38	444
IV. Potash.							
Without potash..	714	564.0	23.8	26.90	82.08	17.39	396
5 Kilogrms. potash ..	854	655.8	28.4	25.77	82.00	17.40	448
10 ,, ,,	830	631.1	49.0	26.16	81.12	18.52	405
15 ,, ,,	868	643.7	29.6	25.66	82.48	17.34	400
20 ,, ,,	832	575.1	31.1	26.75	81.40	18.40	393
25 ,, ,,	905	653.4	34.1	25.37	82.40	17.06	442

Special Manures per tan.	Yield per plot. Straw. grms.	Full grain. grms.	Empty grain. grms.	1000 unhulled grains weigh grms.	100 parts of full grain yield Hulled grain. °/o	Chaff. °/o	Number of panicles per plot.
V. Lime.							
Without lime.	832	575.1	31.1	26.75	81.40	18.04	393
20 kilogrms. lime	879	604.1	44.9	25.41	82.28	16.93	439
40 ,, ,, ...	857	602.9	20.2	25.67	82.80	16.91	431
VI. Green Manure and Lime.							
Without green manure and lime.	459	367.3	15.3	27.42	82.80	16.99	267
Green manure and no lime.	445	361.1	15.2	27.41	82.80	17.45	282
Green manure and 20 kilogrms. lime.	557	464.8	19.4	27.31	81.80	17.34	312
Green manure and 30 ,, lime.	524	432.5	19.4	26.42	82.00	17.45	315
Green manure and 40 ,, lime.	524	434.7	17.6	27.84	83.16	16.60	299

Before entering into the discussion of the influence of the manures on the quantities of grain and straw produced, we may take notice of some features in the development of the plants caused by the different supply of nutrients. As to the *tillering* the following number of panicles were obtained from 1000 plants originally transplanted:

I. Series.

	Unmanured.	Without phosph. acid	Without nitrogen.	Without potash.
	987	1013	1113	1650

II. Series.

Nitrogen, kilogrms.	0	5	7.5	10	12.5	15	17.5
Panicles	1113	1329	1504	1638	1625	1638	1717

III. Series.

Phosphoric acid, kilogrms.	0	5	10	15	20	25	30
Panicles	1013	1154	1429	1554	1638	1638	1850

IV. Series.

Potash, kilogrms.	0	5	10	15	20	25
Panicles	1650	1869	1690	1667	1638	1842

V. Series.

Lime, kilogrms.	0	20	40
Panicle	1638	1829	1796

VI. Series.

Green manure, and lime, kilogrms. of lime ..	0	20	30	40
Panicles	1175	1300	1313	1246

On the unmanured plots there was no gain of panicles by tillering, on the contrary a few plants had perished. The absence of phosphoric acid and nitrogen from the manures, too, prevented any considerable increase by tillering. When however, to a manure otherwise complete, nitrogen was also added (2nd series), a remarkable increase of panicles was noticed; and the same result took place when to a manure complete in other respects but free from phosphates (3rd series), the latter were also admixed. In both these cases the gain of panicles by tillering kept pace, up to a certain limit, with the supply of the said nutrients. The addition of potash to the nitrogenous and phosphatic manure in the 4th series hardly manifested any effect, and the lime, too, in the 5th and 6th series exerted only a slight influence. These observations indicate that on our soil nitrogenous and phosphatic fertilizers, when combined, act most powerfully, while potash and lime are less needed as direct manures, because the soil contains enough of them for the successful cultivation of rice.

The *weight or size of the full* (i.e. normally developed) *grains* is also affected by the different supply of manures, though not to a considerable extent, the greatest difference of the weight of 1000 unhulled grains being less than 2.5 grms. The general law that the more plants are raised on a given area, the smaller is the size of the grains is confirmed by our researches

for the rice crop, especially by the 2nd and 3rd series. The only exception to the rule appeared in the case of the small crop on the plots which had received copious nitrogenous and potassic fertilizers without phosphatic nutrients; owing to this abnormal mixture of nutrients the transportation of organic substance from the leaves into the grain was obviously seriously disturbed. The latter opinion is confirmed by the fact that on those plots the yield of grain (89.7 grms.) was smaller than on the unmanured ones (106.4 grms.), in spite of the large supply of nitrogen and potash.

As the size of the grains is only so slightly affected by the manures, it cannot be expected that *the proportion of hulled grain and chaff* obtained from the full grain should show great variations in the different trials. Indeed, the percentage of chaff is nearly constant throughout all the trials; it varies only between 17 and 18.5.

The *quantity of empty grain* in the various trials shows a distinct relation to the number of panicles gained by tillering. The new shoots sent up from the roots, develop their panicles, of course, later than the original stems, and were just flowering when the hurricane occurred. The injuries done by the latter were accordingly the greater, the more shoots had been produced. Besides this, the cold rainy weather throughout the month of September was also unfavourable to the fertilization of the late flowering panicles.

The effect of the various quantities of manures on the *yield of the rice crop* will be best shown by the following tables which contain the amounts of straw and hulled grain *per tan* ($=\frac{1}{10}$ hektare) in metric and Japanese measures.[6]). The figures given under "corrected yield" are calculated from the quantity of undeveloped grain and the weight of 1000 individual empty grains; they indicate the highest yield obtainable under the most favourable conditions of weather and treatment of crops,

6) 1 *kuwamme* = 3.75652 kilogrms.; 1 *koku* = 180.39 litres. According to numerous weighings of the Tokyo Chamber of Commerce 1 koku of hulled rice weighs 37.514 kuwamme = 142.3 kilogrms.

and will, of course, be attained only exceptionnally, as a small number of flowers always remain sterile. On the other side, the figures for the actual yield of hulled grain represent an exceptionally low produce, such as was obtained after great injury from a hurricane and cold weather in the flowering period. The maximum yield obtainable in practice will accordingly lie between the "actual" and "corrected" yields of the following tables.

I. Series. Unmanured, and Partial Manures.

Manures.	Straw.	Chaff.	Hulled grain,		Straw.	Chaff.	Hulled grain,	
			actually harvested.	corrected yield.			actually harvested.	corrected yield.
	kilogrms.	kilogrms.	kilogrms.	kilogrms.	kuwamme.	kuwamme.	koku.	koku.
1) Unmanured ..	212	29	95	131	57	8	0.67	0.92
2) Without phosphoric acid.. ..	210	25	80	116	56	7	0.56	0.82
3) Without nitrogen.	500	88	331	430	133	23	2.33	3.02
4) " potash..	778	138	506	649	207	37	3.56	4.56

The yield obtained from the unmanured plots distinctly shows that our soil is really in an exhausted condition and incapable of producing a satisfactory crop without appropriate manure. While the farmers in our neighbourhood obtain on an average per tan 1.8-2.0 koku (250—290 kilogrms.) of hulled grain, our unmanured soil gave far less. The application of much nitrogen and potash without a supply of phosphoric acid (trial No. 2) did not increase the crop beyond that obtained without any manure, and even interfered with the formation of grain, while hardly altering the produce of straw. A very considerable increase of grain and straw was caused (in trial No. 3) by the application of phosphoric acid and potash in the absence of any nitrogenous manure. This result indicates that our soil is poor in phosphoric acid, but contains enough available nitrogen for a yield surpassing the general average obtained

under practical conditions. By a joint application of phosphoric acid and nitrogen (trial No. 4) a still larger crop was produced, although no potash was given in this case.

As the general result, this series of trials conclusively shows that of the three essential nutrients *phosphoric acid is in our soil in the relative minimum; nitrogen comes next, while potash seems to exist in it in amounts sufficent for a large produce of rice.* From the following 3 series we shall learn how much of these nutrients may be economically applied.

II. Series. Nitrogen.

Manure per tan: 25 kilogrms. phosphoric acid, 20 kilogrms-potash and the following quantities of nitrogen:	Straw. kilo-grms.	Chaff. kilo-grms.	Hulled grain, actually harvested. kilo-grms.	Hulled grain, corrected yield. kilo-grms.	Straw. kuwamme.	Chaff. kuwamme.	Hulled grain, actually harvested. koku.	Hulled grain, corrected yield. koku.
1) No nitrogen.. ..	500	88	331	430	133	23	2.33	3.02
2) 5 kilogrms. nitrogen	723	121	424	576	193	32	2.98	4.05
3) 7.5 ,, ,,	804	138	474	672	214	37	3.33	4.72
4) 10 ,, ,,	904	138	505	642	241	37	3.55	4.50
5) 12.5 ,, ,,	893	140	515	662	238	37	3.62	4.65
6) 15 ,, ,,	906	155	510	700	241	41	3.58	4.92
7) 17.5 ,, ,,	945	159	513	747	252	42	3.60	5.18

Judging from these results the best economical effect will be secured by an application of 7.5 kilogrms. of easily soluble nitrogen to each tan of our soil. A still larger quantity of this potent nutrient increases, it is true, the grain slightly and the straw considerably, but it is not advisable to apply larger doses of it, because the luxuriant development of the straw renders the crop liable to lodging or to be thrown down by the wind, and also because a copious application of this expensive nutrient will not compensate for the increase of grain and straw even if the feeding value of the latter is incidentally enhanced. It must, however, not be forgotten that our soil is

exceptionally rich in available nitrogen and that the ammonium sulphate applied constitutes the most easily assimilable form of this nutrient, whereas the ordinary nitrogenous fertilizers, brans, rape cake, green plants, farmyard manure, etc., are sure to be less accessible to the roots and may act at a lower rate on the crop. Hence other soils will certainly require more nitrogen than 7.5 kilogrms.

III. Series. Phosphoric Acid.

Manure per tan: 15 kilogrms. nitrogen, 20 kilogrms. potash, and the following quantities of phosphoric acid:	Straw. kilo-grms.	Chaff kilo-grms.	Hulled grain, actually harvested. kilo-grms.	Hulled grain, corrected yield. kilo-grms.	Straw. kuwam-me.	Chaff. kuwam-me.	Hulled grain, actually harvested. koku.	Hulled grain, corrected yield. koku.
1) No phosphoric acid	210	25	80	116	56	7	0.56	0.82
2) 5 kilogrms. " "	454	71	252	342	121	19	1.77	2.40
3) 10 " " "	671	117	445	583	179	31	3.13	4.10
4) 15 " " "	830	147	522	685	221	39	3.66	4.82
5) 20 " " "	918	163	565	749	244	42	3.97	5.26
6) 25 " " "	906	155	510	700	241	41	3.58	4.92
7) 30 " " "	1036	167	578	790	276	45	4.06	5.55

The results of this series again exhibit with great distinctness the importance and efficacy of phosphatic manures on our soil. Every 5 kilogrms. of this nutrient, up to an application of 10 kilogrms., increased the actual yield of hulled grain by nearly 200 kilogrms. (1.3 koku) per tan, and if altogether 15 kilogrms were applied 80-100 more kilogrms. were harvested. This shows that a quantity between 10 and 15, i. e. 12.5 kilogrms. of that nutrient in an easily soluble form will answer the purpose very well and secure an economical result. If phosphoric acid can be procured at low rates, every judicious farmer will follow our advice and apply rather more, especially if his farm is in a district well suited for rice cultivation.

IV. Series. Potash.

Manure per tan: 15 kilogrms. nitrogen, 25 kilogrms. phosphoric acid, and the following quantities of potash:	Straw.	Chaff.	Hulled grain,		Straw.	Chaff.	Hulled grain,	
			actually harvested.	corrected yield.			actually harvested.	corrected yield.
	kilogrms.	kilogrms.	kilogrms.	kilogrms.	kilogrms.	kilogrms.	koku.	koku.
1) No poatsh	778	138	506	649	207	37	3.56	4.56
2) 5 kilogrms. poatsh	930	159	586	749	248	42	4.12	5.26
3) 10 ,, ,,	904	191	558	840	241	51	3.91	5.90
4) 15 ,, ,,	945	157	591	745	252	42	4.15	5.23
5) 20 ,, ,,	906	155	510	700	241	41	3.58	4.92
6) 25 ,, ,,	986	163	586	788	262	43	4.12	5.54

Potash seems to be of less significance in our soil than the two other nutrients experimented on. Already 5 kilogrms. of it sufficed for a maximum produce and, as the ordinary manures used in practice mostly contain considerable proportions of it, special attention need not be bestowed upon it in soils similar to that of our farm. As, however, the stock of available potash varies much in soils of different geological origin, it is possible that in other districts a special supply of potassic manures may be efficacious, especially if the proper amounts of nitrogen and phosphoric acid are applied.

V. Series. Lime, and VI. Series. Green Manure and Lime.

	Straw. kilo-grms.	Chaff. kilo-grms.	Hulled grain, actually har-vested. kilo-grms.	Hulled grain, correct-ed yield. kilo-grms.	Straw. kilo-grms.	Chaff. kilo-grms.	Hulled grain, actually har-vested. kilo-grms.	Hulled grain, correct-ed yield. kilo-grms.
V. Series.								
15 kilogrms. nitrogen, 25 kilogrms phosph. acid, 20 kilogrms potash and the following quantities of lime:								
1) No lime	906	155	510	700	241	41	3.58	4.92
2) 20 kilogrms. lime	957	165	541	803	255	44	3.80	5.64
3) 10 ,, ,,	933	139	543	687	249	37	3.82	4.77
VI. Series.								
Green manure, 25 kilo-grms. phosphoric acid, 20 kilogrms potash and the following quantities of lime:								
1) No lime	485	89	322	421	129	24	2.26	2.96
2) 20 kilogrms. lime	606	115	414	541	162	31	2.92	3.80
3) 30 ,, ,,	571	108	385	506	152	29	2.71	3.55
4) 40 ,, ,,	571	102	394	511	152	27	2.76	3.59
5) No green manure and no lime.. ..	500	88	331	430	133	24	2.33	3.02

The 5th series of our trials shows that an addition of lime to a manure otherwise complete had only a very slight, if any, effect. In these trials, however, nitrogen, phosphoric acid and potash had been so copiously applied that the lime could only act directly, as a nutrient, for which purpose the small quantity existing in our soil already sufficed. Under other conditions this manure has frequently proved to be of decidedly good effect, as it facilitates the decay of nitrogenous organic

sulstances and liberates potash from certain silicates, thus supplying the crop to some extent with assimilable nitrogen and potash. An action of this kind was certainly displayed in the 6th series in all those trials in which the lime was applied along with green manure. While without lime the little *genge* plants had no effect (compare trials 1 and 5), the addition of this indirect fertilizer caused an increase of nearly 100 kilo of hulled grain per tan. As the young plants had, however, not yet far developed before the transplantation of the rice, owing to too late sowing, they could not yet have assimilated much nitrogen from the air, and the question to what extent they may display this action to the benefit of the rice crop, if sown in the preceding year, remains to be answered by experiments in the coming season.

The preceding researches have shown that under the conditions of our soil *the best development of paddy rice is secured by the application of* 7.5 *kilogrms.* (2.0 *kwamme*) *of nitrogen and* 12.5 *kilogrms.* (3.5 *kwamme*) *of phosphoric acid per tan* (=10 are), provided that both nutrients are given in a soluble form; potash and lime, however, have been found to exist in the soil and ordinary manures in quantities sufficient for a luxuriant crop. The yield obtained with the above nutrients amounted under the very unfavourable meteorological conditions of the season to about 500 kilograms (3.5 koku) of hulled grain per tan and may increase in good years up to 650 kilograms (4.5 koku), whereas the general average of the whole empire is, according to the official statistics, only 2 koku. This large difference indicates that the manures commonly applied by the farmers must be deficient either in nitrogen or phosphoric acid or both, and to get clear information on this important question, we collected data[7] on the kinds and quantities of manures used for rice in various parts of the country, and calculated their contents, as follows (per tan in kuwamme):

7 For some of them we are indebted to Prof. Fesca.

	Nitrogen.	Phosphoric acid.	Potash.
1) Tokio[2]).			
10 ka night-soil	1,3	0,3	0,6
10 kuwamme fish manure (shime kasu)	0,9	0,5	—
Total	2,2	0,8	0,6
2) Tokio.			
2 ka night-soil	0,3	0,1	0,1
16 kuwamme fish manure	1,4	0,8	—
Total	1,7	0,9	0,7
3) Tokio.			
6 ka night-soil	0,8	0,2	0,3
10 kuwamme fish manure	0,9	0,5	—
Total	1,7	0,7	0,3
4) Iwashiro.			
250 kuwamme farmyard manure	1,4	0,7	1,3
20 ,, rape cake	1,0	0,4	0,3
Total	2,4	1,1	1,6
5) Iwashiro.			
250 kuwamme farmyard manure	1,4	0,7	1,3
40 ,, rice brans..	0,8	1,5	0,6
Total	2,2	2,2	1,9
6) Iwashiro.			
250 kuwamme farmyard manure	1,4	0,7	1,3
30 ,, shochiu cake	0,9	0,1	—
Total	2,3	0.8	1,3
7) Ise.			
250 kuwamme farmyard manure	0,8	0,4	0,7
20 ,, fish manure	1,8	1,0	—
Total	2,6	2,4	0,7
8) Settsu.			
10 ka night-soil	1,3	0,3	0,6
20 kuwamme fish manure	0,9	0,5	—
Total	2,2	0,8	0,6
9) Fukuoka.			
2 da green manure (grasses)..	0,3	0,1	0,4
125 kin straw	0,9	0,4	1,3
5 ka night-soil	0,7	0,1	0,3
Total	1,9	0,6	2,0

8 Still smaller quantities than the above are not rare round Tokio.

	Nitrogen.	Phosphoric acid.	Potash.
10) Fukuoka.			
2 da farmyard manure	0,2	0,1	0,3
90 kin fish manure (hoshika)..	1,0	0,4	—
Total	1,2	0,5	0,3
11) Fukuoka.			
4 da farmyard manure	0,4	0,2	0,6
20 kuwamme rape cake	1,0	0,4	0,3
6.5 ka night-soil	0,8	0,2	0,4
Total	2,2	0,8	1,3

The total average calculated from these data is found to be per tan:

2.1 kuwamme of nitrogen and
1.0 ,, ,, phosphoric acid.

According to our experiments are required:

2.0 kuwamme of nitrogen and
3.5 ,, ,, phosphoric acid.

The amount of *nitrogen* applied in practice appears to coincide very nearly with that found by the experiments to be required in our farm. As the soil on which the researches were made, contains, however, considerable quantities of available nitrogen, it will be advisable to apply to less rich soils, more than 2 kuwamme, even in those cases in which very easily soluble manures, such as night soil and fish manure are used. If straw, green plants, rape cake, bran, etc. are the principal fertilizers, still more, *viz.* up to 3 kuwamme, should be applied.—As to *phosphoric acid*, the above calculations show that Japanese farmers use far too small a quantity of this nutrient, a fact which I have already frequently pointed out.[9] The scarcity of phosphoric acid in most of the Japanese fertilizers and soils, and the continued cropping must have reduced in the course of centuries the stock of this ingredient to such an extent that in the majority of soils, both paddy and dry land, it exists at present in the relative minimum among the essential vegetable nutrients. It is consequently a most laudable enterprise to manufacture effective phosphatic fertilizers in the country itself, and to teach the farmer how to apply these auxiliary manures,

9 See Bulletin No 3, p. 23—25, and Bulletin No 4, p. 36.

as yet entirely unfamiliar to him. The condition for success is, of course, a reasonable price which should not exceed 24 Sen per Kilogram (90 Sen per Kuwamme) of assimilable phosphoric acid, and at the same time the manure should be high-graded to diminish the expense of transportation. Among the concentrated phosphatic fertilizers manufactured in foreign countries the "*double superphosphates*" or "*biphosphates*" with more than 40% of assimilable phosphoric acid, and *Thomas phosphate powder* containing 17-20% of total phosphoric acid, and 80% of fine powder passing through the standard sieve, deserve to be taken into consideration for the purpose of importation. The former kind, like all superphosphates, is suitable for all soils that are not of a mere sandy or gravelly character, and even on the latter it may be applied if large doses of lime have been incorporated with the soil in preceding years. The Thomas phosphate powder is suitable for all paddy soils, but it must be kept in mind that only about half its phosphoric acid will be available in the first season.

The cost of 2.5 kuwamme of assimilable phosphoric acid which have been found to be deficient per tan in the ordinary manures, is, at present rates 2.25 Yen in the double superphosphate and 3 Yen in the Thomas phosphate. Adding to this the cost of the increase of nitrogen, which will be about 50 Sen, we get as total increase of the manuring expenditure 2.75 resp. 3.50 Yen per tan, by means of which a crop of about 3.5—4 koku of hulled grain can be secured in mean seasons. As 2 koku is the average yield in our neighbourhood and 1 koku is worth at least 4.5 Yen, the profit to be realized by the proposed system of manuring is considerable.

It is furthermore important to remember that the rice crop consumes in the first season only about 20-25% of the assimilable phosphoric applied and that the remainder is left in the soil in an active condition and not liable to be extracted by irrigation or rain. The expense of the auxiliary phosphatic manure is accordingly greatly diminished in the subsequent seasons.

The effect of the various kinds and quantities of fertilizers on the *composition of the straw and the grain*, and the proportions to which the nutrients given entered the crops, were determined by chemical analyses. Owing to lack of time we had unfortunately to confine these researches to determinations of nitrogen, which were made by Kyeldahl's method, and of phosphoric acid, potash, and lime, which were estimated in the ash prepared by incineration of the substance moistened, in the determinations of phosphoric acid, with a solution of barium hydrate.

The *nitrogen* determinations in the crop obtained from the unmanured and partially manured plots and from those supplied with a complete mixture of nutrients containing different doses of nitrogen, gave the following results :—

Manure per tan.	Moisture.		In the dry matter.				
			Nitrogen.			Crude Protein.	
	Grain. °/o	Straw. °/o	Grain. °/o	Straw. °/o	Whole crop.10 °/o	Grain. °/o	Straw. °/o
Unmanured	14.92	15.80	2.230	1.242	1.435	13.88	7.76
No phosphoric acid, 15 kil. nitrogen and 20 kil. potash	15.03	15.94	2.312	1.385	1.561	14.45	8.66
No potash, 15 kil. nitrogen and 45 kil. phosphoric acid	14.56	14.70	1.955	1.000	1.208	12.22	6.25
No nitrogen, 25 kil. phosphoric acid and 20 kil. potash	14.36	15.88	1.713	0.693	1.054	10.71	4.33
Nitrogen Series.							
25 kil. phosphoric acid, 20 kil. potash and the following quantities of nitrogen:							
5 Kilogrms.	14.38	14.71	1.704	0.724	1.043	10.65	4.52
7.5 "	14.56	14.97	1.693	0.765	1.060	10.58	4.78
10 "	14.18	14.48	1, 734	0.817	1.096	10.84	5.11
12.5 "	14.56	12.90	1.790	0.850	1.135	11.19	5.31
15 "	14.28	14.09	1.909	0.904	1.199	11.93	5.63
17.5 "	14.53	14.46	1.914	0.924	1.204	11.96	5.78

According to these results, the proportion of nitrogenous substances in the crops, both in grain and straw were influenced by the manures to a remarkable degree. The *richest in nitrogen* are the products of the unmanured and of those plots which did not receive any phosphatic food; we find in these

10 Incl. the chaff, which contained according to the analysis of a mixed sample 11.69°/o moisture, 0.5186°/o nitrogen, 0.7293°/o phosphoric acid, 0.533°/o potash and 0.0866°/o lime.

trials in the dry matter the following quantities of crude protein (per cent.):

	Grain.	Straw	Total crop[11]
Unmanured	13.94	7.78	8.97
Without phosphoric aci ...	14.45	8.66	9.76

The plants of these trials had absorbed much of the available nitrogen from the soil resp. manure, nevertheless they remained dwarfs, because the quantity of phosphoric acid did not suffice for a better development. The total production of organic matter was dependent on these trials upon the phosphatic ingredients of the soil, which in respect to the other factors of growth were in the relative mimimum. Thus the somewhat striking result was that the unmanured plants produced grain and straw richer in nitrogenous substances than those supplied even with the largest quantities of nitrogenous manures (17.5 kilogrms. per tan) but in conjunction with sufficient phosphoric acid.

On the other hand, the *lowest proportions of nitrogenous substances* in the grain and straw were found in that trial in which much phosphoric acid but no nitrogen had been applied, the percentage amounts of crude protein being in the dry matter

of grain	10.71 %
,, straw	4.33 ,,
,, the total crop[11]	6.59 ,,

As in this case the nitrogen was in the relative minimum among the essential nutrients, the total production of organic substance depended on this factor, and the plants made the most complete use of this nutrient, with the result that in the mature crop the percentage amount of nitrogenous substances was the lowest.

When to a manure, complete in other respects, different quantities of nitrogen were added, the mature crop became the richer in this ingredient, the larger the quantity supplied.

11 Chaff included.

With small doses of nitrogen (5—7.5 kilogrms.) in the manure, the most complete economy of this nutrient took place in the development of the plants, e.g. as large a quantity of organic matter as could be formed with the help of the small quantity of nitrogen, was actually produced and the percentage amount of nitrogenous matters in the ripe crop did not essentially differ from that obtained with a manure free from nitrogen but complete in all other respects. From larger doses (10—17.5 kilogrms.) of nitrogen in the manure the plants absorbed, of course, also more, but the production of organic matter was no longer dependent on this nutrient, because the latter no longer represented the minimum factor. Other conditions, especially light, did not suffice to produce so much as would have corresponded to the large amount of nitrogen taken up, and as a consequence, the resulting ripe crop turned out to be richer in nitrogenous substances, than when small proportions of nitrogen were applied.

As mature seeds represent a complete organism (germ) with a small stock of nutrients for its future development, and of a limited size, a mixture of organic and mineral substances is deposited in them which cannot widely vary in its composition. Manures have accordingly far less influence on the composition of the grain than on the other parts of the vegetable body in which, after maturity, all those substances are left which are taken up or assimilated either in excess of the need or too late to contribute to the production of seeds. Thus we notice also in our trials that the proportions of nitrogenous matters show less variation in the grain than in the straw, though a certain parallelism between the two is distinctly perceptible. In all trials which gave a straw rich in nitrogen, the grain also contains relatively much of it; while, however, in the former the ratio between the lowest and highest contents is 100 : 200, it is in the latter only 100 : 135. Our researches thus indicate that if the straw is to be used for fodder, the supply of nitrogen in the manure should not be too small.

It affords also much interest to ascertain *how much of the*

nitrogen applied was recovered in the crop. The following calculation yields information on this subject.

Nitrogen per tan	Unmanured.	Without Nitrogen.	5 kilogrms.	7.6 kilogrms.	10 kilogrms.	12.5 kilogrms.	15.0 kilogrms.	17.5 kilogrms.
Nitrogen, grammes per plot:								
In the grain	1.65	4.46	5.68	6.30	6.91	7.24	7.66	7.71
,, ,, straw	2.06	2.67	4.10	4.80	5.80	6.07	6.46	6.86
,, ,, chaff	0.13	0.41	0.61	0.64	0.66	0.65	0.72	0.73
Total	3.84	7.54	10.39	11.74	13.37	13.96	14.84	15.30
In the crop produced without nitrog. manure ..	—	—	7.54	7.54	7.54	7.54	7.54	7.54
Assimilated from the manure	—	—	2.85	4.20	6.83	6.42	7.30	7.76
Applied in the manure..	—	—	4.59	6.89	9.18	11.48	13.77	16.07
Assimilated, per cent of the nitrogen applied	—	—	62.1	61.0	63.5	56.0	53.0	48.3

With moderate quantities of nitrogen, such as should be applied in practice, a very high rate of this nutrient has been consumed by the plants; in the average of the first 3 trials (5, 7.5 and 10 kilogrms. of nitrogen) 62.2 % of the nitrogen given were recovered in the crop, a result which very nearly coincides with observations made by P. Wagner[12] on dry land, in which 64 % of that nutrient entered the crop. This result has important practical bearings, showing that ammoniacal salts (ammonium sulphate, night-soil) can be safely applied to paddy soils that have a good absorptive power for

12 P. Wagner, Steigerung der Bodenerträge durch rationelle Stikstoffdüngung.2 . Aufl. 1888, p.68.

ammonia, without running the risk of losing any appreciable amount by the usual irrigation. As special experiments[13] with our paddy soil and with various manures have shown, nitrification does not take place in it while it is being irrigated, because of the deficiency of oxygen and the predominance of reducing processes. Otherwise, if nitrates were formed in paddy soils, a considerable part of them would certainly be washed away by the irrigation, and the rate of the nitrogen assimilation from the manure would probably fall even lower than in the dry fields, on which plants absorb in the first season after the application of ammoniacal salts according to our researches[14] only 40 % of the nitrogen given.—From the large doses 12.5.—17.5 kilogrms. of nitrogen, however, some of the ammonia has been probably washed away as such, the absorptive power of soil being incapable of retaining such large quantities. The rice plants at least consumed in these trials considerably less of it, viz. 56, 53 and 48 % compared with the 62 % which were taken up from the 3 moderate doses. A small quantity was, however, still assimilated, even from the last additional 2.5 kilogrms; the crop of the last trial (17.5 kilogrms.) contains per plot still 0.46 grms. nitrogen more than the preceding plot, while the increase in the manure was 2.3 grms.; 20 % of the latter additional quantity had accordingly still entered the plants.

The percentage contents of the crops in *phosphoric acid* in the plots supplied with this nutrient were, as follows:

13 Not yet published; preliminary trials in Landw. Versuchsstationen, 1883, vol. 30, p 32.

14 See Bulletin 6, p. 31.

Manure per tan:	Moisture		Phosphoric acid in the dry matter.		
	Grain. %	Straw. %	Grain. %	Straw. %	Whole crop[15]. %
Unmanured	14.92	15.80	0.611	0.103	0.240
No phosphoric acid, 15 kil. nitrogen and 20 kil. potash	15.03	15.94	0.618	0.100	0.232
No nitrogen, 25 kil. phosphoric acid, 20 kil. potash..	14.36	15.88	0.766	0.115	0.349
No potash, 25 kil. phosphoric acid and 15 kil. nitrogen	14.56	14.70	0.655	0.126	0.314
Phosphate Series.					
15 kil. nitrogen. 20 kil. potash and the following quantities of phosphoric acid:					
5 kilogrms	14.59	13.44	0.548	0.104	0.245
10 ,, ...	14.31	14.95	0.581	0.123	0 286
15 ,, ...	14.81	14.99	0.600	0.145	0.297
20 ,, ...	14.53	15.06	0.631	0.169	0.320
25 ,, ...	14.28	14.09	0.714	0.174	0.342
30 ,, ...	14.56	16.04	0.727	0.176	0.340

As the phosphoric acid represents in our soil the minimum among the factors of production, it was most completely made use of in the plants of all those plots that received either none or only moderate quantities of it. Hence we find in the dry matter of these crops the smallest proportion of this nutrient, viz.

in the grain ... ... 0.618 %
,, ,, straw ... ... 0.100 ,,
,, ,, whole crop[15] ... 0.232 ,,

When, however, in consequence of a rich supply the phosphoric acid was no longer in the relative minimum among the factors of growth, the crops became gradually richer in it, proportionately to its amount in the manure, for the same reason

15 Chaff included.

as given on the preceding pages with reference to the absorption of nitrogen from highly nitrogenous manures. The largest quantities were accordingly found on the plot most copiously manured with (30 kilogrms.) phosphoric acid and on that which likewise received much of this nutrient and of potash but no nitrogen; in those cases there was contained in the dry matter:—

	Complete manure, rich in phosphoric acid	Without nitrogen
of the grain	...0.727 %	0.766 %
,, ,, straw	...0.176 ,,	0.115 ,,
,, ,, whole	...0.340 ,,	0.349 ,,

It is remarkable that the crop very liberally manured with phosphoric acid, but not supplied with nitrogen did not contain very much of the phosphoric acid in the straw. The reason for this unexpected result certainly is the early ripening of the plants. Owing to the deficiency of nitrogen in the soil these plants could not produce sufficient albuminoid for all the cells, wherefore the albuminoids from the older leaves were transported in an early period to the newly developing organs, leaving the former in so exhausted a condition that they soon turned yellow and dried up. As a considerable part of the vegetable body was thus put out of function, the absorption of phosphoric acid which takes place generally somewhat slowly, could not be continued to the same extent as by the plants copiously supplied with both nitrogen and phosphoric acid.

Again we find here the variations in the composition to be larger in the straw than in the grain. In the former the relative proportion between the minimum and maximum content is 100: 176, in the latter 100: 140.

An *account of the absolute quantities of phosphoric acid that entered the crops* from the manures is given in the following table:

Phosphoric acid per tan.. ..	Un-manured	Without Phosph. Acid.	5 kilo-grms.	10 kilo-grms.	15 kilo-grms.	20 kilo-grms,	25 kilo-g rms.	30 kilo-grms.
Phosphoric Acid, grammes per plot:								
In the grain	0.45	0 39	1.08	2.04	2.45	2.80	2.86	3.30
,, ,, straw	0.17	0.16	0.38	0.65	0.94	1.21	1.24	1.41
,, ,, chaff	0.02	0.02	0.05	0.07	0.09	0.11	0.10	0.11
Total	0.64	0.57	1.51	2.76	3.48	4.12	4.20	4.82
In the crop produced without phosphoric acid	—	—	0.57	0.57	0.57	0 57	0.57	0.57
Assimilated from the manure..	—	—	0.94	2.19	2.91	3.55	3.63	4.25
Applied in the manure	—	—	4.59	9.18	13.77	18.36	22.95	27.54
Assimilated, per cent of the phosphoric acid applied.. ..	—	—	20.5	22.8	21.1	19.4	15.9	15.4

Rice plants are accordingly capable of taking up of the soluble phosphoric acid applied in doses of 5—25 kilogrms per tan, 20—25%, which rate does not differ from the results obtained in practice with other crops. From exceedingly large dressings, however, noticeably less is consumed, viz. from 20—30 kilogrms. only 15—16%. Thus, considerable quantities of this valuable nutrient are left in the soil even after the application of moderate doses, and will doubtless act beneficially in the next season.

The *proportions of potash found in the mature crop* were, as follows, per cent of the dry matter:—

Manure per tan:	Moisture.		Potash in the dry matter.		
	Grain. %	Straw. %	Grain. %	Straw. %	Whole Crop. %
Unmanured	14.92	15.80	0.289	0.998	0.705
No potash, 25 kil. phosphoric acid and 15 kil. nitrogen	14.56	14.70	0.304	0.469	0.429
No nitrogen, 25 kil. phosphoric acid and 20 kil. potash	14.36	15.88	0.330	1.620	1.053
No phosphoric acid, 15 kil. nitrogen and 20 kil. potash	15.03	15.94	0.315	1.004	0.876
Potash Series.					
25 kil. phosphoric acid, 15 kil. nitrogen, and the following quantities of potash:					
5 kilogrms	14.41	15.37	0.284	0.702	0.547
10 ,, ...	14.59	15.28	0.293	1.005	0.710
15 ,, ...	14.44	14.84	0.314	1.252	0.865
20 ,, ...	14.28	14.09	0.328	1.507	1.043
25 ,, ...	14.35	14.53	0.318	1.518	1.026

The supply of various quantities of potash had likewise a very marked influence on the content of the crops in this substance. The richest were those plants which had received a manure consisting of much potash and phosphoric acid but destitute of nitrogen, and the poorest were those supplied with, much nitrogen and phosphoric acid, but to which no potash had been given. In the former case potash was largely in excess among the factors of growth, and copiously entered the plants without being needed for the production of organic matter; in the latter case the plants had at their disposal only the potash originally contained in the soil, which was consequently worked up to the utmost extent. In these two extreme trials the content of potash was as follows (per cent of dry matter):—

	Grain.	Straw.	Whole crop
Minimum	0.304	0.469	0.429
Maximum	0.330	1.620	1.053

In the crops dressed with much nitrogen and phosphoric acid and supplied with different doses of potash, the contents of the crop in this substance show a distinct relation to the supply, except in the last trial with 25 kilograms of potash per tan, in which case the plants no longer consumed considerably more than in the preceding trial with 20 kilograms. Here certainly we reached the maximum limit of the diffusion of potash into normally developed rice plants.

Just as in the nitrogen and phosphate series, the composition of the grain was also here less influenced by the manure than by the straw. While in the former the proportion between the lowest and highest content of potash was 100 : 116, it was in the latter 100 : 345.

The following calculation shows how much potash was consumed from the manure:

Potash per tan	Unmanured.	Without potash.	5 kilogrms.	10 kilogrms.	15 kilogrms.	20 kilogrms.	25 kilogrms.
Potash, grammes per plot:							
In the grain	0.22	1.21	1.31	1.28	1.46	1.32	1.47
,, ,, straw	1.65	2.91	5.08	7.07	9.25	10.77	11.74
,, ,, chaff	0.02	0.66	0.78	0.90	0.69	0.74	0.79
Total	1.89	4.78	7.17	9.25	11.40	12.83	14.00
In the crop produced without potash	—	—	4.78	4.78	4.78	4.78	4.78
Assimilated from the manure			2.39	4.47	6.62	8.05	9.22
Applied in the manure ..	—	—	4.59	9.18	13.77	18.36	22.95
Assimilated, per cent of the potash applied	—	—	51.9	48.7	48.1	43.8	40.2

The rate of potash consumed from the manure nearly comes up to the high proportion of nitrogen assimilated from ammoniacal fertilizers. If moderate doses of potash are applied, the rice plants take up nearly half of them. From excessively large dressings less (only 40%) is consumed.

The preceding researches still furnish valuable information as to the *stock of nutrients available to the rice crop in our soil.* We found in the crop produced with a sufficient supply of phosphoric acid and potash, but without any nitrogen in the manure, a quantity of *nitrogen* amounting to 8.542 grms. The little plants raised in the seed beds and used in the experiments contained, according to an analysis:

	In 1000 individual plants	Per frame. 240 plants.
Dry matter	85.63 grms	20.55 grms.
Nitrogen	1.527 ,,	0.366 ,,
Phosphoric acid ...	0.362 ,,	0.087 ,,
Potash	0.770 ,,	0.192 ,,
Lime	0.177 ,,	0.043 ,,

Upon deducting 0.366 grms. of nitrogen from the quantity obtained in the mature crop, we get 7.176 grms., which must have been taken up from the stock in the soil. Assuming this nitrogen to have been consumed in the form of ammonia and taking into account that from the ammoniacal compounds in the soil rice plants can absorb, according to our results (p. 28), 62.2%, we come to the conclusion that our soil contained per plot 11.54 grms. of nitrogen *equivalent in efficacy to ammoniacal nitrogen.* This makes per tan 12.57 *kilogrms. of available nitrogen.*

As to *phosphoric acid*, the crops harvested without any supply of this nutrient from the unmanured plots and from those manured with copious quantities of nitrogen and potash, contained in the average per plot 0.605 grms. As in the 240

young plants applied per plot there were only 0.087 grms., the amount absorbed from the soil was 0.519 grms., and as from the phosphoric acid only 21.5% can be taken up by the plants (p. 32), the available quantity is found to be per plot 2.41 grms. or per tan 2.60 *kilogrms. of phosphoric acid, equivalent in efficacy to phosphoric acid soluble in water.*

Finally, as regards *potash*, the crop produced without any supply of this nutrient but with copious nitrogen and phosphoric acid, contained 4.78 grms., from which quantity 0.19 grms. must be deducted as having already been in the young plants. Hence 4.59 grms. of potash had been taken up from the soil. As from moderate doses of potash manure rice plants are capable of consuming 50%, the stock of available potash in our soil is 9.18 grms per frame or 10 *kilogrms. per tan.*

By adding to the stock of available nutrients thus calculated the amounts of nitrogen and phosphoric acid[15] needed as manure on our soil, we get figures which express the quantity of nutrients needed by a full rice crop under the climatic conditions and mode of cultivation of our neighbourhood.

Kilogrms. per tan:	Nitrogen.	Phosphoric. acid.
Needed in the manure,	7.5	12.5
Contained in the soil	12.6	2.6
Total	20.1	15.1

If these results should be confirmed by researches on other soils and under other conditions, they would represent a most important basis for the determination of the amount of fertilizers to be applied to rice. By three trials, viz.

1) 15 kilogrms. of phosphoric acid and 12.5 kilogrms of nitrogen;

2) 15 kilogrms. of phosphoric acid and 15 kilogrms. of potash;

3) 12.5 kilogrms. of nitrogen and 15 kilogrms. of potash;

each of which must be carried out on 3 or 4 small plots, and by

16 As the 10 kilogrms. of available potash per tan of our unmanured land appeared to suffice to the crops, we cannot, of course, extend our calculations to this nutrient.

determining in the crop of No. 1 the amount of potash, in No. 2 that of nitrogen, and in No. 3 that of phosphoric, we should be enabled to tell exactly how much of *available* nutrients exist in the soil experimented on and how much must be added in the manure. For the latter purpose it is, of course, necessary to know the rate to which the nitrogen and phosphoric acid of the various forms of manures is available to the rice in the 1st, 2nd, and 3rd year. Researches which we intend to carry out in the coming season will help us to arrive at such a rational and solid basis for the manuring of the most important crop of this country.

ERRATA,

in Bulletin No. 7.

Page 7, table, read in the column No. III, total nitrogen 5.29, instead of 4.03; and albuminoid nitrogen 4.03, instead of 2.88.

Yield of the Single Plots.

No. of plot.	Manure per tan.	Straw. grms.	Total grain. grms.	Full grain. grms.	Empty grain. grms.	Number of panicles.
	I. Series. Unmanured, and Partial Manures.					
8	Unmanured	202	112.0	103.8	8.2	243
12	,, ...	207	136.5	130.0	5.7	239
32	,, ...	227	124.4	116.9	8.5	235
36	,, ...	174	105.4	100.4	5.0	238
61	,, ...	173	84.1	79.3	4.8	224
65	,, ...	208	113.8	108.0	5.8	240
11	No P_2O_5, 14 kil. N & 30 kil K_2O	169	95.5	89.0	6.5	266
35	,, ,, ,, ..	190	92.7	87.1	5.6	223
64	,, ,, ,, ..	220	100.4	93.0	7.4	240
9	No, N, 25 kil. P_2O_5 & 20 kil K_2O	446	375.6	359.0	16.6	264
33	,, ,, ,, ..	427	392.2	382.5	9.7	256
62	,, ,, ,, ..	504	380.0	360.4	19.6	281
10	No K_2O, 25 kil. P_2O_5 & 15 kil. N	726	592.2	561.3	30.9	404
34	,, ,, ,, ..	691	564.7	544.5	20.2	405
63	,, ,, ,, ..	724	606.6	586.1	20.5	380
	II. Series. Nitrogen. 25 kil. P_2O_5, 20 kil. K_2O and the following:					
1	5 kil. N..	647	467.0	444.0	22.8	303
13	,, ,, ,, ...	660	509.0	485.0	24.0	314
20	,, ,, ,, ...	686	521.7	495.8	25.9	340
2	7.5 kil. N	714	495.6	456.8	38.8	345
14	,, ,, ...	712	553.9	332.1	21.8	369
21	,, ,, ...	788	624.7	592.3	32.4	370
3	10 kil. N	868	514.2	489.1	25.0	367
15	,, ,, ...	779	620.9	603.3	17.6	394
22	,, ,, ...	843	638.4	615.8	22.6	418
4	12.5 kil. N	849	596.4	574.6	21.9	359
16	,, ,, ...	755	575.4	555.8	20.2	387
23	,, ,, ...	857	626.1	596.5	29.6	423

No. of plot.	Manure per tan.	Straw. grms.	Total grain. grms.	Full grain. grms.	Empty grain. grms.	Number of panicles.
5	15 kil. N	875	590.2	566.0	24.2	380
17	,, ,, ...	754	580.1	555.5	24.6	390
24	,, ,, ...	876	646.4	603.8	42.6	409
6	17.5 kil. N	841	578.8	547.5	31.3	401
18	,, ,, ...	891	609.2	577.0	32.3	408
25	,, ,, ...	873	651.3	599.0	51.3	428
	III. Series. Phosphoric Acid.					
	15 kil. N, 20 kil. K_2O and the following:					
27	5 kil. P_2O_5	402	289.8	275.8	14.0	266
37	,, ,, ...	449	328.4	313.1	15.3	279
42	,, ,, ...	401	269.7	255.5	14.2	285
28	10 kil. P_2O_5	589	497.5	476.0	21.5	339
38	,, ,, ...	668	531.7	507.1	24.6	348
43	,, ,, ...	583	496.4	473.0	23.4	342
29	15 kil. P_2O_5	779	633.9	609.5	24.4	357
39	,, ,, ...	798	594.4	568.0	26.4	377
44	,, ,, ...	710	599.5	574.5	25.0	385
30	20 kil. P_2O_5	855	688.4	657.0	31.4	411
40	,, ,, ...	922	682.5	652.2	30.3	388
45	,, ,, ...	751	622.3	598.0	24.3	380
31	30 kil. P_2O_5	991	669.3	631.5	37.8	471
41	,, ,, ...	954	695.1	658.3	36.8	429
46	,, ,, ...	907	678.8	652.3	26.5	432
	IV. Series. Potash.					
	15 kil. N, 25 kil. P_2O_5 and the following:					
47	5 kil. K_2O	861	688.8	663.6	25.2	446
57	,, ,, ...	848	678.3	648.0	30.4	451
72	,, ,, ...	(705)	(517.1)	(492.5)	(24.6)	(362)
48	10 kil. K_2O	868	717.1	665.0	52.1	427
58	,, ,, ...	792	643.1	597.2	45.9	384
73	,, ,, ...	825	(564.6)	(536.8)	(27.8)	395

No. of plot.	Manure per tan.	Straw. grms.	Total grain. grms.	Full grain. grms.	Empty grain. grms.	Number of panicles.
49	15 kil. K_2O	868	695.5	653.6	41.9	419
59	,, ,, ...	873	680.3	658.1	22.2	386
74	,, ,, ...	864	640.7	619.5	21.2	394
50	25 kil. K_2O	932	697.3	656.0	41.3	446
60	,, ,, ...	857	686.2	661.6	24.6	440
75	,, ,, ...	926	679.0	642.5	36.5	439
	V. Series. Lime.					
	15 kil. N 25 kil. P_2O_5 20 kil. K_2O					
54	20 kil. CaO	782	604.7	575.2	29.5	418
68	,, ,, ...	900	638.7	585.5	53.2	446
77	,, ,, ...	957	703.2	651.5	51.7	454
55	40 kil. CaO	816	693.5	648.7	44.8	414
69	,, ,, ...	850	590.1	548.3	41.8	436
78	,, ,, ...	905	643.2	611.7	31.5	443
	VI. Series. Green Manure and Lime.					
	25 kil. P_2O_5, 20 kil. K_2O, green manure.					
7	No lime	481	359.0	342.0	17.0	271
19	,, ,, ...	433	390.3	374.3	16.0	311
26	,, ,, ...	420	379.6	367.0	12.6	265
51	20 kil. CaO	514	449.0	428.5	20.5	299
56	,, ,, ...	604	521.8	504.5	17.3	316
70	,, ,, ...	552	481.9	461.3	20.6	321
52	30 kil. CaO	526	484.4	467.5	16.9	335
66	,, ,, ...	512	436.2	421.5	14.7	308
71	,, ,, ...	534	435.2	408.5	26.7	302
53	40 kil. CaO	486	448.2	423.0	25.2	265
67	,, ,, ...	581	455.9	442.8	22.8	316
76	,, ,, ...	505	453.1	438.3	14.8	316

I. SERIES.
UNMANURED, AND PARTIAL
MANURES.

V. SERIES. LIME.

per tan				
Nitrogen, kilogrms.	0	15	0	15
Phosphoric acid ,,	0	0	25	25
Potash ,,	0	20	20	0

0 lime. — 20 kilogrms. lime. — 40 kilogrms. lime.

General Manure: 15 kilogrms nitrogen, 25 kilogrms, phosphoric acid and 20 kilogrms, potash.

II. SERIES. NITROGEN.

Nitrogen per *tan*: 0 | 5 kilogrms. | 7.5 kilogrms. | 10 kilogrms. | 12.5 kilogrms. | 15 kilogrms. | 17.5 kilogrms.

General Manure per *tan*: 25 kilogrms. phosphoric acid and 20 kilogrms. potash.

III. SERIES. PHOSPHORIC ACID.

Phosphoric acid,
kilogrms. per *tan*: 0 5 10 15 20 25 30

General Manure per *tan*: 15 kilogrms. nitrogen and 20 kilogrms. pot

IV. SERIES. POTASH.

Potash, kilogrms, per *tan* · 0 5 10 15 20 25

General Manure per *tan* : 15 kilogrms, nitrogen and 2[illegible] [illegible]grms phosphoric acid.

農科大學
學術報告
第九號

IMPERIAL UNIVERSITY.

College of Agriculture.

(FORMERLY IMPERIAL COLLEGE OF AGRICULTURE AND DENDROLOGY).
KOMABA, TŌKYŌ, JAPAN.

BULLETIN NO. 9.

Researches on the Action of Lime as a Manure,
with special regard to Paddy Fields,
and
Experiments on the Cultivation of
Lespedeza bicolor, Turcz. (Hagi),
as a Forage Crop.

Communicated

BY

DR. O. KELLNER,
Professor of Agricultural Chemistry.

明治二十四年二月

TŌKYŌ, KOMABA, FEBRUARY, 1891.

PRINTED BY [illegible]SHA, GINZA, TŌKYŌ.

Researches on the Action of Lime as a Manure, with Special Regard to Paddy Fields,

CARRIED OUT IN CONJUNCTION WITH

H. Sakano, D. Sato, and S. Shinjo,

BY

Dr. O. Kellner.

In many districts of Japan large quantities of lime, up to 300 *kuwamme* per *tan*,[1] have been annually applied to rice in the paddy fields, and continue to be resorted to, in spite of conspicuous injury which is caused by this habit, and affects both soils and crops. Owing to the entrance of lime into the constitution of silicates and the presence of abundant moisture, the mineral particles of the soil are liable to be cemented together, either a few feet below the surface, as I had occasion to observe in the Miye prefecture near Yokkaichi, or on the surface itself, as M. Fesca[2] reports from the prefecture of Chiba. Not only is the treatment and cultivation of the soil rendered difficult by this action of lime, but stagnation of water may follow as it is prevented from draining into the deeper layers. At the same time potash and ammonia are liberated by lime and are liable to be washed away by the irrigating water, whence the soil gradually impoverishes so much that in order to supply these essential nutrients to the rice crop, the Japanese farmer again decomposes in the subsequent season insoluble ingredients of the soil by repeating every year the dressing with lime, which he is even compelled sometimes to increase. He is quite aware of the fact that the same kind and quantity of manure which

(over 10,0 per ac

1 1 tan = 0.0992 hektar; 1 kuwamme = 3.7565 kilogrms.

2 Beiträge zur Kenntniss der Japanischen Landwirthschaft. 1. Theil, 1890, p. 275.

secured a satisfactory yield before he resorted to heavy doses of lime, no longer suffices for a good produce unless he applies lime too. He, moreover, knows that, if he discontinues the use of lime, he must supply his fields with a larger dose of more expensive manures, which his circumstances unfortunately do not generally permit. When in feudal times local governments prohibited the use of lime, the farmers tried to evade punishment by liming their fields in the night.

Experience has long ago taught the European farmers the valuable lesson that lime is an exhaustive manure, the frequent application of which impoverishes the land. German farmers say: "frequent liming makes the father rich but the son poor" or "the lime cart must be followed by the manure cart," and in England people are familiar with the proverb:

"Lime and lime without manure,
Makes the son and father poor."

Complete infertility as a consequence of overliming, has indeed been experienced also in Japan in several localities; and other districts will doubtless suffer ere long. No time should therefore be lost in enlightening the agricultural population with reference to the ruinous consequences of frequent liming, and inducing the farmers to entirely cease using this manure or, at least, to resort to it only every 3 or 4 years, except, of course, in special cases in which it is applied to cure sour land, to diminish the stiffness of heavy clay soils, or to make coarse sand less porous, etc.

It is peculiar that not only is the crop feeding power of the soil impaired by lime but that it also deteriorates the rice crop. According to information obtained through Mr. *D. Sato*, a graduate of our college now on the staff of the Tochigi prefecture at Utsunomiya, the stems become, in consequence of too much lime, less flexible, being liable to be broken down by the wind; wherefore the straw is rendered unfit for various braiding industries. The grain is even more affected than the straw.

It acquires an inferior taste and lustre and becomes lighter, the hulls grow thicker, the white spots in the grain become larger, and sensible losses are experienced during the hulling and cleaning, because the grains being brittle break during these operations.

My attention was called to the latter point on the occasion of the third national exhibition in Tokyo, and as similar observations have not yet been made with any of the other cereals, and were therefore of considerable interest, I procured through Mr. S. Kikkawa 5 specimens of hulled rice from the province of Iyo in Shikoku, which proved to be exceedingly brittle. The chemical examination of these grains was made under my control by Mr. *S. Shinjo*, a graduate of the college. Regarding their origin and the manures applied the five specimens were accompanied by the following notes :

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Soil	Dry sand.	Dry black loamy soil.	Dry clayey soil.	Wet dark soil.	Loam.
Variety	Takara-toku.	—	Yego-mai.	Uwa-mai.	Shira-tama.
Lime, kuwamme ..	50	40	40	un-known.	un-known.
Other manures, kuwamme per tan.. ..	60 rice straw, 40 wax berry cakes.	200 green manure, 300 horse dung.	200 green manure, 300 horse dung, 10 oil-cake	7 koku, mud from rivers.	200 green manure, 3 koku oil-cakes.

Specimen No. 1 (Takaratoku) was subjected to a complete analysis, the results of which accompanied by those of several other analyses of ordinary hulled rice grown without lime near Tokyo, were the following :

	Takara-toku.	Shiratama.	Shinriki.	Shinshyu wase.
Moisture	15.98 %	14.20 %	14.46 %	14.55 %
In the dry matter:				
Crude protein ...	9.25 ,,	9.84 ,,	10.42 ,,	10.94 ,,
,, fat	2.16 ,,	2.66 ,,	2.84 ,,	2.68 ,,
,, fibre	1.24 ,,	1.45 ,,	2.21 ,,	1.93 ,,
Nitrogen-free extract	85.82 ,,	85.03 ,,	83.35 ,,	83.15 ,,
Ash free from sand and coal	1.47 ,,	1.02 ,,	1.18 ,,	1.30 ,,
Sand	0.06 ,,	— ,,	— ,,	— ,,
Total nitrogen ...	1.481 ,,	1.574 ,,	1.667 ,,	1.760 ,,
Albuminoid nitrogen	1.397 ,,	1.442 ,,	1.500 ,,	1.514 ,,
Non-albuminoid nitrogen	0.084 ,,	0.132 ,,	0.167 ,,	0.246 ,,
In 100 *parts of the ash:*				
Potash	22.00 ,,	22.94 ,,	23.45 ,,	22.63 ,,
Soda	2.75 ,,	4.94 ,,	5.17 ,,	4.81 ,,
Lime	4.08 ,,	3.24 ,,	2.98 ,,	3.36 ,,
Magnesia	9.63 ,,	10.54 ,,	11.97 ,,	10.85 ,,
Ferric oxide... ...	3.78 ,,	1.03 ,,	0.93 ,,	1.30 ,,
Phosphoric acid ...	52.10 ,,	51.37 ,,	51.26 ,,	50.39 ,,
Sulphuric acid ...	1.27 ,,	1.85 ,,	1.08 ,,	1.82 ,,
Silica	3.78 ,,	3.14 ,,	2.91 ,,	3.19 ,,
Chlorine	2.60 ,,	1.05 ,,	0.98 ,,	1.14 ,,

The rice under examination appears accordingly to be somewhat *poor in crude protein*, while with regard to the other ingredients no clue can be detected which in any way explains the peculiar brittle condition of the grain. The proportion 9.25% of crude protein must indeed be considered as low, as in exact manuring experiments made in 1889 in our college,[3]

3 Bulletin of the Imperial College of Agriculture and Dendrology No. 8, p. 25.

we found in the grain produced on a plot supplied with phosphatic and potassic manure, but with no nitrogenous fertilizers, the content to be 10.71% of the dry matter.[4] Pursuing our investigations in this line we determined the crude protein also in the four other specimens and found the following contents:

	No. 2	No. 3	No. 4	No. 5
Moisture	16.18 %	16.38	16.16	16.35
Crude protein in the dry matter	8.76	9.06	8.54	10.12

We must confess that we did not expect to find so simple an explanation of the brittle condition of overlimed rice, but had cherished the idea that something in the composition of the ash or in the proportion of carbohydrates would give us a clue to the elucidation of this peculiar action of lime. We were accordingly surprised to meet in the case of rice with a fact which has already been justly maintained to be the reason for the glassy or mealy condition of barley and wheat, which also differ only in their content in nitrogenous compounds, the mealy grains being poorer in them than the glassy or horny ones. But with regard to these cereals, overliming has never been noticed as the cause of their mealy condition. Large doses of nitrogenous manures are known to increase the proportion of horny grains in the case of barley and wheat, but, opposed to the case of rice, this property deteriorates their value, because glassy barley produces a sort of malt which, in beer brewing, resists saccharification and yields an insufficient amount of carbohydrates in the mash; and the glassy condition of wheat interferes with the porosity of the bread made from it.

For the sake of reference the following results obtained in an

4 The compilations of analyses of human foods or agricultural products do not yield proper information on this point, as in them cleaned and uncleaned rice has been indiscriminately mixed up. (Compare I. König, Zusammensetzung der menschlichen Nahrungs- und Genussmittel, 3. Aufl., 1889, p. 569).

experiment with barley in the province of Saxony, Germany,[5] may be quoted here:

Kind of barley	Saxonian.	Danish.	Moravian.	Slavonian.
Crude protein in the grain.				
Original seeds	8.10	7.70	7.70	7.70
Manure per hektare 100 kilogrms chilisaltpeter.	9.19	9.16	9.18	8.92
Manure per hektare 200 ,, ,,	9.48	9.56	9.78	9.52
Percentage proportion of mealy grains				
Original seeds	80.0	90.0	90.0	92.0
Manure per hektare 100 kilogrms chilisaltpeter.	62.4	70.1	68.7	77.5
Manure per hektare 200 ,, ,,	64.9	65.9	66.8	64.7

This table conclusively shows (1) that the proportion of nitrogenous compounds in the grain depends, within certain limits, on the supply of nitrogen in the manure, and (2) that barley poor in crude protein contains more mealy grains than when it is rich in nitrogenous components.—Similar observations were made before the above researches by Millon, W. Schuhmacher, Th. Siegert, A. Nowacki, and recently also by Th. Dietrich.

To resume our subject, the crucial test for ascertaining whether the fact revealed by our researches is actually connected with an insufficient resistibility to pressure or dynamical forces, was now plain before us: We had to decide whether rice grains poor in protein break under a less pressure than those rich in protein. For this purpose we used a very simple instrument, viz. a graduated lever fixed on one end and lying horizontally on a block on which an unhurt hulled rice grain

5 Biedermann's Centralblatt für Agriculturchemie, vol. 14, 1885, p. 696.

was placed between thin zinc plates. Light weights, 300 grams, were then suspended on the lever, first near the block and then at gradually increasing distances. After 15 seconds' action of the weight, the lever was lifted and the grain examined to see whether it was fractured. If no crack could be perceived, the pressure was increased until the grain broke. From the distances of the block and weight from the fixed point of the lever and the weight applied, the pressure required to crack each grain could be calculated according to well known physical laws. Of each kind of rice at least 25 grains were subjected to this test, and gave, in general, sufficiently concordant results, the greatest variations being, for example, in the case of Takataroku rice 0.25 kilograms. The average results obtained in this way are recorded in the following table:

No.	Content of crude protein in the dry matter %	Pressure to break the grains. kilograms.
1)	8.54	3.24
2)	8.76	3.15
3)	9.05	3.17
4)	9.25	3.20
5)	9.54	3.95
6)	10.12	3.13
7)	10.71	4.18
8)	10.84	4.21
9)	10.98	4.08
10)	11.26	4.34
11)	11.93	4.29

An exact proportionality between the contents in protein and the hardness of the grains can not, of course, be anticipated, as the individuality, the variety and manners of drying and storing the grain are probably not without influence. But the above figures certainly suffice to justify the opinion arrived

at from the chemical analysis, and if we eliminate the variations of less significance by taking the average of the results of the test of every 3 kinds of grain, we get the following figures:

Average of	Content of crude protein in the dry matter %.	Pressure to break the grain, kilograms.
No. 1—3	8.78	3.15
„ 4—6	9.64	3.43
„ 7—9	10.84	4.16
„ 10—11	11.60	4.32

There can be no doubt according to results so plain as these, that *the proportion of nitrogenous compounds plays an important part in the resistibility of the rice grains to pressure or impact.* As brittleness is a consequence of overliming, and as the proportion of crude protein in rice depends, as we have shown in the preceding bulletin (No. 8, p. 25), upon the supply of nitrogen in the manure, it is obvious that large doses of lime applied every year must interfere in some way with the supply of nitrogen from the soil to the crop. How this is accomplished has now to be considered.

Paddy rice prefers, according to researches made in our college by the author and Mr. *J. Sawano*, ammonia as nitrogenous food, and does not thrive well, as long as it is irrigated, if supplied with nitrates alone. Moreover in the paddy fields while they are being irrigated, none of the nitrogenous manure is converted into nitrates, as we shall have to show further on, but ammoniacal compounds are generated from the decaying organic manures, and this ammonia is firmly retained by most soils, because it forms, with organic matters and double silicates, compounds which are but sparingly soluble in water. Lime, however, liberates ammonia from these compounds taking itself the place of the latter and favoring in this way the washing away of this nutrient by the irrigating water. On the other side, it accelerates the decay of the organic manures incorporated in the paddy field, as we shall likewise prove later

on. Thus, large doses of lime repeatedly applied year by year, render the soil poor in nitrogenous food, and as a consequence the grain obtained from such land becomes poor in crude protein. *The brittleness of the rice grown on overlimed soil, is accordingly due to an indirect action of the lime, which favors the loss of nitrogenous nutrients from the soil, thus reducing the formation of albuminoids in the plant and their accumulation in the grain.*

In all cases where lime has been frequently applied and the injuries are manifest in the crop, the use of this manure should be entirely given up for a considerable number of years. Fertilizers rich in organic matter, which are chiefly resorted to in conjunction with liming, such as green manure, farmyard manure, oil-cakes, rice brans, etc., will produce good effects on such soils also without the application of lime, if they are incorporated with the land 2-4 weeks before transplanting the rice; but the dose of manures especially of the oil-cakes, brans, etc. should be so increased in the first years after discontinuing the ruinous liming, as to supply the rice plants with about 25% of nitrogen more than formerly.[6] Where the amount of lime hitherto applied has been small, the above kinds of manures should be thoroughly fermented before they are mixed with the soil. Unless this is done, they undergo a sort of fermentation in the soil itself whereby organic acids are produced in such large quantities and the free oxygen in the soil is so completely absorbed that the plants are injured during the first period of growth, and although they mostly recover 2-3 weeks later, they never attain that vigour which they would have acquired, had they not been thus injured. Lime which neutralizes the free acids, paralyzes, it is true, this bad action of fresh organic manures, and also from this point of view farmers may attach much value to its use, but they would fare better if they bestowed more care on the preparation of a well decomposed compost for the paddy land, instead of using

6 Lime seems to increase the yield of grain only by $\frac{1}{6}$-$\frac{1}{5}$, if it is applied with other direct fertilizers.

the manures in a raw state in conjunction with lime. All soils that have received lime in preceding years are specially suited for the application of superphosphates as an addition to the above mentioned fertilizers. A quantity of 1-1.5 kuwamme of soluble phosphoric acid in the first year, and of 0.5-0.75 kuwamme in the subsequent seasons would enhance the yield of grain so much that farmers would not think any more of returning to heavy and frequent doses of lime.

A second important factor in the cultivation of overlimed paddy fields is the selection of suitable *varieties of rice.* Some of them, as for example *shiratama* (white spot) is particularly liable to become mealy and brittle, as its grains do not acquire, even on normal soils, a uniform texture but always exhibit more or less white spots near the surface and in the centre. Other varieties are, on the other side, more apt to retain their horny compact condition even under unfavourable circumstances, as we had occasion to observe with *oni no ude* (devil's arm), which endured a pressure of 5.5 kilogrms., whereas *shiratama* produced on the same soil with the same manure, broke under a pressure of 3.95 kilogrms. We regret, however, that we must abstain from recommending any special varieties for overlimed soils, because we are not aware of the special local conditions in the various provinces, which must, of course, also be taken into account in the selection.

Finally, the inconvenient mealy condition of rice may be diminished to some extent by *early cutting.*

We must add that the brittle condition of the rice grains is not necessarily due only to overliming, but may be experienced in all those cases in which the supply of nitrogen to the plants is insufficient. It may also be caused in some instances by faulty methods of drying and storing the grain.

In the preceding pages lime was alluded to as *favouring the decay of organic manures in the soil and accelerating the formation of ammonia* from nitrogenous organic compounds. We

have observed that the insufficient nitrogen supply to the plants in overlimed soils is associated with this action so far as the ready formed ammonia is prevented from being absorbed and retained in the soil by the presence of much lime, and is therefore liable to be washed away by the irrigation, before it can be taken up by the roots. This opinion is founded on some researches made, under my control, likewise by Mr. *S. Shinjo.*

That lime accelerates the decay of organic materials in dry land, is a fact long since known in European countries, as is indicated by the epithet "hungry" applied to calcareous soils because of the rapid destruction of humus producing manures in them. With reference to soils kept under water for several months during the summer and retaining much moisture also in the winter, as is the case with paddy soils, since no observations or researches have as yet been recorded, we felt constrained to investigate this subject. To clear up the question, we did not confine our work to paddy soil alone, but made *comparative trials on the action of caustic lime on the decomposition of organic matter in both dry and paddy soils,* proceeding in the following way:

Several kilograms of dry and paddy earth from the fields of the college were dried in the air, sifted and mixed, separately for each trial, with a certain proportion of finely powdered soy beans. The soils and beans had the following composition in the air-dry state:

	Dry land soil.	Paddy soil.	Soy beans.
Moisture	31.18 %	37.10 %	9.05 %
Mineral matter ...	52.62 ,,	45.62 ,,	4.46 ,,
Organic matter and combined water ...	16.20 ,,	17.28 ,,	86.59 ,,

In several of the trials slaked lime was applied which had been freshly prepared from calcium oxide made from marble, and which contained 81.93% of calcium hydrate (CaO_2H_2)

and 10.43% calcium carbonate. The following mixtures were made :[7]

A. DRY LAND SOIL.

I. 290.55 grms. air-dry soil = 200 grms. dry matter, 10.995 grms air-dry soy beans = 10 grms. dry matter, and 50 c. c. water.

II. The same mixture with the addition of 14.375 grms. slaked lime = 10 grms. CaO.

B. PADDY SOIL.

I. 317.965 grms. air-dry soil = 200 grms. dry matter, 10.995 grms. air-dry soy beans = 10 grms dry matter, and 300 oo water.

II. The same mixture with the addition of 14.375 grms. slaked lime = 10 grms. CaO.

These mixtures were put into spacious wide-mouthed glass bottles and closed air-tight with twice perforated rubber plugs furnished with glass pipes, through which every two days air free from carbon dioxide was guided over the soil but which were otherwise kept closed. From time to time samples of the mixture were taken out from the bottles and submitted without delay to determinations of dry matter, organic matter and combined water, carbon dioxide, and mineral matter free from carbon dioxide.[8]

The results of these investigations are compiled in the following table :—

7 As to the slaked lime we should mention that for every trial so much was weighed out as corresponded exactly to 10 grms. of calcium oxide (CaO).

8 The two kinds of original soil were free from carbonates.

A. DRY LAND SOIL.

Trial No. I.	After 2 weeks.	After 4 weeks.	After 6 weeks.
Soil and soy beans.			
Moisture	39.14	38.80	38.62
Dry matter	60.86	61.20	31.38
Mineral matter	44.66	45.01	45.23
Organic matter and combined water	16.20	16.19	16.15
Trial No. II.			
Soil, soy beans and lime.			
Moisture	39.26	39.32	40.29
Dry matter	60.74	60.68	59.71
Carbon dioxide	1.41	1.10	0.73
Dry matter free from CO_2	59.33	59.58	58.98
Mineral matter	46.11	46.54	46.25
Carbon dioxide therein	1.17	1.05	0.86
Mineral matter free from CO_2 ...	44.94	45.49	45.39
Organic matter and combined water	14.39	14.08	13.59

B. PADDY SOIL.

Trial No. I.			
Soil and soy beans.			
Moisture	58.30	47.54	39.90
Dry matter	41.69	52.46	60.09
Mineral matter	28.96	36.52	41.93
Organic matter and combined water	12.73	15.94	18.16
Trial No II.			
Soil, soy beans and lime.			
Moisture	48.61	45.52	36.75
Dry matter	51.38	54.48	63.25
Carbon dioxide	0.38	0.35	0.25
Dry matter free from CO_2	51.00	54.13	63.00
Mineral matter	36.82	39.16	45.46
Carbon dioxide therein	0.45	0.37	0.14
Mineral matter free from CO_2 ...	36.37	38.79	45.32
Organic matter and combined water	14.63	15.34	17.68

Calculating now from these figures how much organic matter and combined water was contained in the mixtures at the various periods of their examination for every 100 parts of mineral matter free from carbon dioxide, we get the following figures :

A. Dry land soil.	Original mixture.	After 2 weeks.	After 4 weeks.	After 6 weeks.
Trial No. I, without lime	36.90	36.28	35.95	35.71
,, ,, II, with lime	34.64	32.02	30.96	29.94
B. Paddy Soil.				
Trial No. I, without lime	44.30	43.97	43.74	43.32
,, ,, II, with lime	41.45	40.25	39.53	39.03

With the help of these results we find that from 100 parts of organic matter and combined water originally applied the following quantities were destroyed during the experiment:

A. Dry land soil.	Without lime.	With lime.	Difference.
After 2 weeks	1.69	7.55	5.86
,, 4 weeks	2.57	10.61	8.04
,, 6 weeks	3.24	13.58	10.34
B. Paddy Soil.			
After 2 weeks	0.74	2.91	2.17
,, 4 weeks	1.27	4.64	3.37
,, 6 weeks	2.21	5.85	3.64

The slaked lime contained, as the analysis given for it shows, some carbon dioxide besides combined water, but in all the above calculations of the dry matter, and organic matter and combined water, it was reckoned only as calcium oxide (CaO), because in the mixtures the combined water is soon liberated in the conversion of the hydrated oxide into carbonate, as well as in its neutralization by the organic compounds of the soil. The carbon dioxide was eliminated from the calculations, because the greater part of it found after the decomposition of the organic matter, is a product of this process not originally contained in the substances

applied, and also because its proportion varies in the course of the decomposition.

The analytical methods applied in the above researches did not admit of a separate determination of organic matter and combined water, wherefore the final results given in the last table comprise the loss of both these substances and are valid for the organic matter alone, only if the amount of combined water in the mixtures did not alter in the experiment. This supposition must indeed be admitted as valid because any appreciable alterations in the amount of combined water could not have been caused otherwise than by the entrance of lime into the constitution of silicates. Such however did not take place in the case in point because the proportion of organic matter in the soils and carbon dioxide produced was so large in the experiment that it sufficed to speedily neutralize the calcium hydrate applied. We find, indeed, in the mixture of dry land soil with soy beans and lime after two weeks standing, so much carbon dioxide (2.27 calculated to the original substance) that it even surpassed the quantity (2.00%) which was required to convert the whole lime into carbonate ($CaCO_3$). In this form the lime could not easily affect the constitution of the silicates, and accordingly it could not alter the proportion of combined water. In the course of time some of the carbonate was decomposed, most probably by the organic acids existing in the humus and originating in the further decay of it as well as in that of the soy beans.—The above figures showing the loss of solid materials from the mixture, accordingly also yield reliable information as to the decomposition of the organic matter in the soils. We may deduce from them the following conclusions:

(1) Lime accelerates the decomposition of organic matters in both dry land and irrigated paddy soils.

(2) This action is accomplished in dry land to a far larger extent than in irrigated soils.

(3) In general, the organic matter is decomposed in dry soils more rapidly than in irrigated ones.

Comparative researches on the formation of nitric acid and ammonia from nitrogenous manures in dry land and paddy soils were carried out in conjunction with Mr. *D. Sato* in 1888, and some attention was given at the same time to the influence of lime on this process. A series of glass jars, 20 centimetres high and of a diameter of 15 centimetres were filled in March with soil which had been allowed to dry in the air only so far as not to involve any destruction of the micro-organisms, in order to separate the coarse rootlets with the help of sieves. The determination of the nitrogenous ingredients in the sifted samples gave the following results:

	Dry land soil.	Paddy soil.
Hygroscopic water	41.12 %	42.12 %
Humus and combined water	14.06 ,,	21.61 ,,
Total nitrogen	0.231 ,,	0.455 ,,
Nitric acid	0.098 ,,	0.048 ,,
Ammonia	0.009 ,,	0.024 ,,
Nitrogen in organic compounds ...	0.198 ,,	0.418 ,,

Of the dry land soil 1600 grms., and of the paddy soil 1400 grms. were used for each trial. Some of the jars received nitrogenous manures viz. ammonium sulphate and finely powdered fish manure and in some cases 50 grms. of freshly precipitated calcium carbonate. The content of nitrogen in the vessels (9 with dry land and 9 with paddy soil) at the beginning of the researches were as follows (in grams):

	Dry land soil.		Paddy soil.	
1) No manure	3.702	—	6.366	—
2) Ammonium sulphate ...	6.302	2.600	8.466	2.100
3) Fish manure	6.302	2.600	8.466	2.100
4) Unmanured	3.702	—	6.366	—
5) Ammonium sulphate ...	6.302	2.600	8.466	2.100
6) Fish manure	6.302	2.600	8.466	2.100
7) Ammonium sulphate ...	6.302	2.600	8.466	2.100
8) Fish manure without lime	6.302	2.600	8.466	2.100
9) Fish manure with lime ...	6.302	2.600	8.466	2.100

The percentage amount of nitrogen applied in the manure was accordingly in the dry land soil 0.162%, in the paddy soil 0.150%.

After filling, the jars were digged into the respective fields up to about 5 centimetres from the upper edge, and the paddy soil was irrigated with distilled water, the level of which was kept throughout the whole time of the experiment about 2 centimetres above the surface of the soil. The jars on the dry land were merely kept at the same degree of moisture as the surrounding field. To prevent dust and rain from entering the vessels, large glass plates were suspended over them. After standing for some time we determined the quantities of nitric acid, according to Schulze-Tiemann's method, and of ammonia, according to the method elaborated by A. Baumann,[9] the only modification being that the ammonia was thrown down with platinic chloride from which we weighed the platinum after ignition. The results calculated per jar, were the following :

A. DRY LAND SOIL.

No. of jar.	Manure.	Length of the experiment, days.	Nitric acid. grms.	Ammonia. grms.
—	Original soil	—	0.095	0.140
1	No manure	30	0.096	0.143
2	Ammonium sulphate	30	0.455	2.846
3	Fish manure	30	0.715	1.427
4	No manure	84	1.132	0.129
5	Ammonium sulphate	78	2.368	2.225
6	Fish manure	84	3.675	0.415
7	Fish manure without lime ..	122	3.961	0.242
8	,, ,, with lime ..	122	4.532	0.129

9 Landw. Versuchsstat., vol. 32, p. 257.

B. PADDY SOIL.

No. of jar.	Manure.	Length of the experiment, days.	Nitric acid. grms.	Ammonia. grms.
—	Original soil	—	0.047	0.384
1	No manure	36	0.049	0.411
2	Ammonium sulphate	36	0.081	not determined.
3	Fish manure	36	0.057	,,
4	No manure	64	0.045	,,
5	Ammonium sulphate	58	0.047	,,
6	Fish manure	64	0.007	,,
7	Fish manure without lime ..	114	0.116	1.054
8	,, ,, with lime ..	114	0.074	1.478

These results plainly show 1) that in our dry land soil the nitrogenous manures were speedily converted into nitric acid, while no such process took place in the irrigated paddy soil; in the latter, ammonia seems to be among the principal products of the decomposition of nitrogenous organic fertilizers; and 2) that the application of lime distinctly favours on one ~~side~~, the nitrification in the dry land, and on the other, the formation of ammonia in the paddy soil.

The fact of the non-occurrence of nitrification in paddy soils, shown by the above researches had already been noticed by me and Mr. J. Sawano in a preliminary trial made in 1882[10] and was considered by us to be due to the deficiency of oxygen and the presence of much organic matter in the irrigated soils. Observations made since by others, indeed, corroborate this opinion. Thus A. Baumann[11] found that nitric acid occurs only in minute traces in the common forestial soils in Germany which are usually very rich in humus; and A. Muntz[12] proved that in soils micro-organisms commonly occur which

10 Landw. Versuchsstat., vol. 30, p. 33

11 Ibid., vol. 33, p. 247.

12 Biedermann's Centralblatt für Agriculturchemie. 19. Jahrg., 1890, p. 736.

have a capacity for producing ammonia and prepare the nitrogenous substances for the subsequent nitrification. In those soils such as marshes, bogs, and peat, the chemical composition of which prevents nitrification, the decomposition ends, according to this author, in the formation of ammonia. In course of time the ammonia may be again reconverted into organic compounds by the numerous fungi and algae which inhabit the soil in general.

Many of the constituents of soils, organic as well as inorganic, have a strong chemimal affinity to the ammonia thus produced, and protect it usually very well from being washed away in the course of the irrigation. Lime, however, particularly if applied as oxide or hydrate, is likewise apt to be absorbed, and if incorporated with the soil, occupies some of the places in which otherwise the ammonia would find protection, or dislodges it from the compounds into which it had already entered. Thus losses of nitrogenous substances take place and the field gradually becomes impoverished in this very essential vegetable nutrient in consequence of frequent liming, as we have already pointed out.

In soils poor in lime but rich in ferric compounds *the application of lime seems to favour the action of soluble phosphatic fertilizers on crops.* In an experiment made last year to ascertain the manurial value of various kinds of phosphates for rice, we compared, amongst several others, sodium phosphate and double superphosphate, and were surprised to find that the latter had a far better effect than the former. As both these are soluble in water and are speedily absorbed when they are mixed with our soil, the difference in their effect must have been due to the combination into which they enter in the soil. Sodium phosphate is sure to yield there chiefly phosphates of iron and alumina while the double superphosphate which almost entirely consists of monocalcium phosphate will most probably be converted ni

equal proportions into dicalcium phosphate and phosphates of iron and alumina. Among these products the calcium compound is certainly more accessible to, and assimilable by, the roots, than the other phosphates.

To clear up this subject, Mr. *H. Sakano*, who after his graduation continued his studies in the laboratory, carried out under my advice and control a series of researches. Two kinds of soils were applied, one from our paddy fields, the other from the deeper portions of the subsoil of the dry fields. Both were rich in easily decomposable silicates and iron compounds; the paddy soil[13] was also very rich in humus; the subsoil, however, almost entirely destitute of organic matter. Specimens of the two soils were dried in the air only so far that a portion of them could be sifted off for the trials, in order not to destroy all the fungi normally existing in them. A number of bottles of a capacity of about 50 c.c. were filled with the soils, each bottle receiving 10 grms., besides the following quantities of quick lime prepared from marble:

TOP SOIL FROM PADDY FIELD.

Bottle No. ..	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12
Lime, grms. ..	0	0.025	0.05	0.10	0.25	0.5
,, , percent of the soil.	0	0. 25	0. 5	1. 0	2. 5	5.0

SUBSOIL.

Bottle No.	1 and 2	3 and 4	5 and 6	7 and 8
Lime, grms...	0	0.025	0.10	0.50
,, , percent of the soil.	0	0. 25	1. 0	5. 0

After liming, every vessel received 20 c.c. distilled water, and after 2 week's standing 0.05 grms. of phosphoric acid were added in the form of monopotassium phosphate specially prepared for the purpose and dissolved in so much water, that 5 c.c. of the solution just contained the above quantity

13 Analyses of the paddy soil will be found in bulletin No. 8, p. 3-4.

of phosphoric acid. All the bottles were then kept under a spacious bell glass to prevent the mixtures from drying up. We believe that by these arrangements we did not much deviate from the ordinary conditions of the fields, either with regard to the mode of applying the manures or with respect to the quantities of lime and phosphate.

One, resp. two months after the application of the phosphatic manure we determined how much of the phosphoric acid had been converted into compounds soluble in neutral *ammonium citrate* of a specific gravity of 1.09, a reagent which is at present most widely used in the analysis of commercial phosphatic fertilizers for the purpose of determining how much of their phosphoric acid is available for plants. The analysis was carried out in the usual way. The contents of each bottle were rinsed with 100 c.c. of neutral citrate into a small bulb and heated in a water bath to 30-40° C for 30 minutes, whereupon the solution was filled up to 250 c.c. from which 200 c.c. were evaporated after the addition of a little cream of lime, and incinerated. The ash was repeatedly dissolved in strong nitric acid and again evaporated in order to separate the dissolved silicic acid. The filtrate from the latter, always exactly 100 c.c., was precipitated with ammonium molybdate and the precipitate treated in the usual way. The quantities of phosphoric acid dissolved from the soil by ammonium citrate, were found to be as follows:

Lime applied. grms.	Paddy field. Top soil.		Dry land. Subsoil.	
	Phosphoric acid dissolved.		Phosphoric acid dissolved.	
	grms.	per cent of the quantity applied.	grms.	per cent of the quantity applied.
After 1 month.				
0	0.0063	12.7	0.0037	7.4
0.025	0.0075	15.1	0.0026	5.3
0.050	0.0089	17.8	—	—
0.100	0.0113	22.6	0.0039	7.8
0.250	0.0113	22.6	—	—
0.500	0.0112	22.5	0.0039	7.9
After 2 months.				
0	0.0057	11.5	0 0037	7.5
0.025	0.0072	14.4	0.0028	5.7
0.050	0.0085	17.1	—	—
0.100	0.0116	23.3	0.0043	8.6
0.250	0.0136	27.2	—	—
0.500	0.0135	27.1	0.0042	8.5

These results plainly prove that in the top soil of the paddy field the presence of lime had an action decidedly beneficial to the preservation of the assimilability of the phosphoric acid applied in a soluble form, and that under the conditions of our experiment the maximum effect was already displayed by 0.1—0.25 grms., i. e. 1—2.5 % of lime in the air-dry soil. While in the trials without lime only 12.7 % of the whole soluble phosphoric acid added remained in a state soluble in citrate solution, the addition of 1 % of the said fertilizer to the soil previous to the admixture of the phosphate nearly doubled this quantity, after the soil had been allowed to stand for one month. It even appears that upon a longer action of the lime, after 2 months, some of the phosphate previously precipitated in a more insoluble form was rendered soluble in citrate solution by the presence of 0.25 grms. of lime per bottle, i. e. 2.5 %. How this slight after-effect was accomplished,

cannot, of course, be deduced from the above researches, but it is not unlikely that the bicarbonate of lime gradually originating in consequence of the continual slow production of carbon dioxide from the humus bodies, acted upon the ferric phosphate, converting a part of it into free ferric hydrate and calcium phosphate. This opinion was verified by me in the following manner:

Freshly prepared precipitates of basic ferric phosphate containing equal quantities of phosphoric acid 0.05 grms. in each case were rinsed into bottles with 200 c.c. of well water, mixed with 500 c.c. of saturated lime water, and a current of pure carbon dioxide was then guided through the bottles for 3 days. Other bottles which had received, instead of lime water, an equal volume of well water were treated in the same way. Thereupon the solutions were decanted through purified asbestos, acidified with nitric acid, evaporated to a small volume, which was tested with a solution of ammonium molybdate for the presence of phosphoric acid. The result was negative as might have been anticipated. The deposit in the bottles consisting in one case of ferric phosphate alone, in the other of this compound mixed with calcium carbonate, were then transferred on to a filter. A moderately concentrated solution of acetic acid was poured upon both the deposits and the filtrate was examined as to the presence of phosphoric acid. That ferric phosphate which had been merely treated with carbon dioxide yielded only a trace of its acid to the dissolvent applied, while from the phosphate treated with lime water and carbon dioxide 0.007 grms. = 14 % of the total phosphoric acid present, passed into the filtrate.[14] This observation proves that a chemical reaction must have been accomplished between a part of the ferric phosphate and the calcium hydrate or bicarbonate

14 It will be understood that this quantity represents only a part of the phosphate which had exchanged ferric hydrate for lime, because upon treatment with acetic acid some of the phosphoric acid which is dissolved from the calcium compound, will recombine with ferric hydrate and become insoluble.

which latter originated from the hydrate in the current of carbon dioxide. Such a process will, of course, also take place in soils between the basic phosphates of iron and freshly applied lime which will display its action there also in both forms, as hydrate and bicarbonate; as a result the crops will be benefited as to their nutrition with phosphoric acid.—Similar processes are certainly accomplished still more easily between calcium compounds and ferrous phosphate; the latter, though easily assimilable as such, is liable to be occasionally oxidized to the less assimilable ferric phosphate, but would be prevented from this change, if its acid combined with lime.[15]

Contrary to its beneficial action on the phosphates in the paddy soil, lime did not affect them to any appreciable extent in the irrigated subsoil from the dry field. As the two soils are of the same geological origin, having, as to their mineral matter, a very similar composition, and differing only in the content of humus which is abundant in the paddy soil but almost entirely absent from the yellow subsoil, there can be no doubt that in our case the humus played an important part in bringing about the action of lime on phosphates. The mineral part of the soil used consists of a large proportion of hydrated silicates with which the lime combines unless it is absorbed by substances which have a stronger affinity to it. The humus and the carbon dioxide generating in the paddy soil probably united at once with the lime when it entered the soil, and thus preserved it in a state in which it could still act on the soluble phosphate, while in the subsoil destitute of humus nothing interfered with the union of the lime with the hydrated silicates. We do not, however, believe that in all soils poor in

15 Upon boiling basic ferric phosphate, containing 0.1 grms. of phosphoric acid and 0.225 grms. of ferric oxide, with lime water in absence of carbon dioxide, rapidly filtering and treating the content of the filter with a hot 5 percentage solution of acetic acid, 64.1 °/₀ of the phosphoric acid applied passed into the filtrate. The same quantity of basic ferric phosphate when digested in the cold for 72 hours with lime water, collected on a filter and extracted with hot 5 percentage acetic acid, yielded 42.2 °/₀ of the phosphoric acid applied, to the extract.

humus the application of lime will exert no influence on the assimilability of phosphoric acid, as the richness of the soil, applied by us, in hydrated silicates is rather an exception. In the majority of cases, as in sandy, clayey, and ordinary loam soils of paddy fields, a moderate dressing with lime previous to the application of superphosphates will certainly secure a good effect of the phosphoric acid on the crop, especially if the soils are ferruginous and would otherwise favour the formation of less assimilable basic phosphates of iron and alumina. For the same reasons in overlimed soils superphosphates are sure to have a good effect.

Regarding the habit of frequent applications of large doses of lime, our researches prove that the exhaustive action of this manure is not confined to nitrogenous and potassic nutrients, but likewise, as was hitherto unknown, favours the consumption of the phosphatic ingredients of the soil by the crops.

IMPERIAL UNIVERSITY
College of Agriculture
Bulletin No. 9
Tokyo, Komaba, Feb. 1891.

Experiments on the Cultivation of Lespedeza bicolor, Turcz. (Hagi) as a Forage Crop,

BY

Dr. O. Kellner, T. Yoshii, and M. Nagaoka.

Lespedeza bicolor Turcz., var. intermedia, Maxim., commonly known by the name *hagi* or *miyagi no hagi*[1] is a wild leguminous plant which is found in all parts of Japan, from the north of Hokkaido to the south of Kyushyu on uncultivated land in the plains as well as in the mountains up to a considerable height. Its stems grow 1—2 metres high and, if allowed to stand for several years, attain a diameter of 1—1.5 centimetres and become so woody and ramified that the plant has much the appearance of a shrub. If cut in the winter or spring, the roots throw up in April or the beginning of May numerous strong shoots which produce small pink coloured flowers in August or September and small very hard seeds, one in each pod, towards October. The character of *hagi* as a leguminous plant, and its general appearance enables us to conclude that fodder made from it in a proper stage of growth will have nutritious qualities. Farmers seem indeed to have experienced its feeding value to be good, as they occasionally collect it from uncultivated lands, though they have never tried to raise in the fields.

The frequent occurrence of this plant on poor soils and its continual growth without any supply of manure induced us to cultivate it experimentally on the farm as a forage crop. In the early spring of 1886 we collected *hagi* roots from the neighbouring waste land and planted them on a plot of 25 square metres in rows, 40 centimetres distant from each other and with a

1 For the botanical determination of this plant we are indebted to Messrs. Shirai and Matsumura, professors in the College.

space of 25 centimetres between the plants. Manure was not supplied. The plants developed in the course of the summer to a height of about 1.3 metres, and after having cast off their leaves, the stems were cut in the winter of 1886—87. In the following season 3 cuttings were taken, on May 29th, August 12th, and October 9th, 1887. The yield, kilograms per *tan*, was as follows:

	Green fodder. Kilogrms.	Hay. Kilogrms.
1. Cutting	...1161.5	315.9
2. ,, ...	...1202.6	390.8
3. ,, ...	... 256.3	93.0
Total ...	...2620.4	799.7

Compared with the medium yields of the ordinary leguminous forage crops in Europe, where lucerne produces per *tan* about 800 kilogrms. of hay, red clover 600, and lupines 500 kilogrms., the amount of fodder obtained from the *hagi* field appears to be quite satisfactory.

The chemical analysis of the three cuttings gave the following results:[2]

2 In these, as in all the following analyses, the crude fibre is free from ash and crude protein, and the ash is free from coal and carbon dioxide.

	Water.	Crude Protein.	Crude Fat.	Crude Fibre.	Nitrogen-free Extract.	Ash.
	%	%	%	%	%	%
Green Fodder.						
1st cutting..	78.21	4.44	0.93	6.96	8.39	1.07
2nd ,, ...	73.44	4.00	1.19	10.07	10.05	1.25
3rd ,, ...	69.41	6.53	1.61	8.39	12.20	1.86
Hay.						
1st cutting..	19.95	16.30	3.43	25.56	30.84	3.92
2nd ,, ...	18.28	12.30	3.67	30.99	30.90	3.86
3rd ,, ...	14.28	18.29	4.53	23.52	34.15	5.23
Dry Matter.						
1st cutting..	—	20.36	4.29	31.93	38.52	4.90
2nd ,, ...	—	15.05	4.49	37.92	37.82	4.72
3rd ,, ...	—	21.34	5.28	27.44	39.84	6.10

With the help of these figures we find the three cuttings to contain the following proportions of nutrients per *tan* in kilograms:

	1st cutting.	2nd cutting.	3rd cutting.	Whole crop.
Dry matter	253.1	319.4	78.4	650.9
Organic matter	240.7	303.6	73.6	617.9
Crude protein	51.5	47.1	16.6	115.2
,, fat	10.9	14.3	4.1	29.3
,, fibre	80.8	121.1	21.5	223.4
Nitrogen-free extract	97.5	120.8	31.2	249.5
Ash (free from CO_2 and C)...	12.4	15.8	4.8	33.0

Calculated from these and the analytical results, the composition of the whole crop harvested during the year, is as follows:

	Dry matter.	Hay of 16°/₀ moisture.
Moisture	—	16.0
Crude protein	17.7	14.9
,, fat	4.5	3.8
,, fibre	34.3	28.8
Nitrogen-free extract	38.4	32.3
Ash	5.1	4.2

Judging from these figures, we find that *hagi* hay has very nearly the same composition as hay of lucerne, which according to E. von Wolff contains: moisture 16.0%, crude protein 14.4%, crude fat 2.5%, crude fibre 33.0%, nitrogen-free extract and ash 6.2%. The green fodder from *hagi* too does not greatly differ from green lucerne, the former containing 75.1, the latter when cut at the beginning of blossoming 74.0% of moisture.

It was our intention to continue these researches as long as possible on the same land in order to determine how long a satisfactory yield of fodder can be obtained, but owing to changes in the college the plot was needed for other purposes and we had to commence the trials afresh in another part of the farm. Accordingly, in the spring of 1888 an area of about 300 square metres was planted with *hagi* roots partly taken from our former experimental field, partly from the uncultivated land round our farm. In the following winter the stems were again cut at a height of about 4 centimetres above the ground, and in the two subsequent seasons (1889 and 1890) three cuttings were taken every summer. In the spring of 1890 a late frost destroyed many of the young shoots, but in their place new ones sprang up a little later. The injury had, however, no serious consequences, and merely retarded the time of cutting for about 3 weeks. In the winter of last season the field was supplied with about 100 kilograms of slaked lime per *tan*, which was harrowed in during fine weather.

The produce of green fodder and hay was as follows, kilograms per *tan*:

	Green fodder.	Hay.
1889.		
1st cutting, May 24th ...	...1624.8	342.8
2nd ,, July 19th ...	... 826.1	248.4
3rd ,, October 14th	... 433.7	172.5
Total	...2884.6	763.7
1890.		
1st cutting, June 14th...	...1690.1	496.9
2nd ,, September 10th.	1021.4	410.1
3rd ,, November 13th.	83.4	27.4
Total	...2794.9	934.4

The yield of green fodder and hay was accordingly very nearly the same as in the crop of 1887, and there was no diminution of the produce in the 2nd of year of cultivation.

The chemical analysis of the fodders gave the following results :[3]

3 The analysis of the 1st cutting of 1890 was made by Mr. T. Yamada, and that of the 3rd cut by Mr. S. Uchiyama.

	Water.	Crude Protein.	Crude Fat.	Crude Fibre.	Nitrogen-free Extract.	Ash.
	°/o	°/o	°/o	°/o	°/o	°/o
Green Fodder.						
1889.						
1st cutting	82.55	3.70	0.87	6.22	5.99	0.67
2nd ,, ...	73.91	4.01	0.76	9.02	10.87	1.43
3rd ,, ...	64.43	6.88	1.81	11.56	13.40	1.92
1890.						
1st cutting	75.21	3.41	0.61	10.17	9.55	1.05
2nd ,, ...	66.55	5.39	0.93	12.48	13.40	1.25
3rd ,, ...	70.88	6.07	1.21	7.08	12.82	1.94
Hay.						
1889.						
1st cutting	17.45	17.57	4.12	29.48	28.19	3.19
2nd ,, ...	12.93	13.39	2.52	30.92	35.48	4.76
3rd ,, ...	13.08	16.81	4.43	28.25	32.73	4.70
1890.						
1st cutting	15.70	11.61	2.07	34.60	32.45	3.58
2nd ,, ...	16.79	13.41	2.30	31.05	33.35	3.10
3rd ,, ...	11.36	18.46	3.70	21.57	39.01	5.90
Dry Matter.						
1889.						
1st cutting	—	21.28	4.99	35.72	34.15	3.86
2nd ,, ...	—	15.37	2.90	35.51	40.81	5.41
3rd ,, ...	—	19.33	5.09	32.50	37.68	5.40
1890.						
1st cutting	—	13.77	2.46	41.04	38.49	4.24
2nd ,, ...	—	16.12	2.77	37.31	40.07	3.73
3rd ,, ...	—	20.83	4.17	24.33	44.01	6.66

As to the character of the nitrogenous compounds, we found in the dry matter:

	Total Nitrogen. %	Albuminoid Nitrogen. %	Non Albuminoid Nitrogen, percent of total Nitrogen.
1889, 1st cutting	3.405	2.638	22.5
,, 2nd ,,	2.459	2.208	10.2
,, 3rd ,,	3.093	2.569	16.9
1890, 1st cutting	2.203	1.949	11.5
,, 2nd ,,	2.579	2.069	19.8
,, 3rd ,,	3.334	3.040	9.0

With the help of all these results we calculate the quantities of nutrients contained in each cutting as follows, kilograms per *tan*:

	Dry Matter.	Organic Matter.	Crude Protein.	Crude Fat.	Crude Fibre.	Nitrogen-free Extract.	Ash.
1889.							
1st cutting	283.0	272.1	60.2	14.1	101.1	96.7	10.9
2nd ,,	216.3	204.6	33.2	6.3	76.8	88.3	11.7
3rd ,,	149.9	141.8	29.0	7.6	48.7	56.5	8.1
Total.	649.2	618.5	122.4	28.0	226.6	241.5	30.7
1890.							
1st cut	418.9	401.1	57.7	10.3	171.9	161.2	17.8
2nd ,,	341.2	328.5	55.0	9.4	127.3	136.8	12.7
3rd ,,	24.3	22.7	5.1	1.0	5.9	10.7	1.6
Total.	784.4	752.3	117.8	20.7	305.1	308.7	32.1

While the proportion of nutrients in the crop of 1889 very closely coincides with that of 1887, some differences will be perceived between the composition of the harvest of 1890 and those of the two preceding years. We notice in the above last tabular record a considerable increase (135.2 kilogrms.)

of the total yield of dry matter, but find that this surplus almost entirely consists of crude fibre (78.5 kilogrms.) and nitrogen-free extract (67.2 kilogrms.), the crude protein, fat and mineral matters showing hardly any alteration. This observation has some practical bearing; it indicates that whenever an easily digestible fodder rich in protein is desired from *hagi*, it must be cut at a far earlier period of growth than the common leguminous forage crops, otherwise the formation of fibre proceeds so far as to interfere with the digestibility. The best time for the first cutting seems to us to be the middle of May, in southern parts of Japan, of course, still earlier; the second harvest may be taken about the middle of July, and the third cut about the middle of October. In no case should the plants be allowed to stand till they are in full flower.

The percentage composition of the whole crops of the two seasons is illustrated by the following figures:

	Hay		Dry Matter.	
	1889	1890	1889	1890
Moisture	...14.89	16.05	—	—
Crude protein	...16.05	12.61	18.86	15.02
,, fat	... 3.67	2.22	4.31	2.64
,, fibre	...29.70	32.66	34.90	38.90
Nitrogen-free extract	...31.66	33.04	37.20	39.35
Ash	... 4.03	3.43	4.73	4.09

In order to ascertain to what extent the soil is exhausted by the cultivation of *hagi*, we analyzed the ash of the crop of 1889 and obtained the following results:[4]

4 The analysis of the first cut was made by Mr. S. Shinjo and that of the 3rd cut by Mr. H. Sakano.

In 100 parts of ash, free from coal and carbonic acid:

	1st cutting.	2nd cutting.	3rd cutting.
Potash	...29.00	30.61	18.47
Soda	...12.81	1.14	3.90
Lime	...22.58	34.33	40.99
Magnesia	... 4.40	4.62	4.71
Ferric oxide	... 3.34	1.74	2.10
Phosphoric acid ...	...12.47	10.45	8.55
Sulphuric	... 3.98	2.46	2.46
Silica	... 9.36	13.61	16.09
Chlorine	... 0.58	1.16	0.54

The amount of important mineral nutrients withdrawn from the soil in the *hagi* crop of 1889 is accordingly as follows, kilograms per *tan*:

	Total Ash.	Potash.	Phosphoric acid.	Lime.	Magnesia.
1st cutting..	10.9	3.16	1.36	2.46	0.48
2nd ,, ...	11.7	3.58	1.22	4.02	0.54
3rd ,, ...	8.1	1.50	0.69	3.32	0.38
Total	30.7	8.24	3.27	9.80	1.40

In medium crops of lucerne (800 kilogrms.) and red clover (600 kilogrms.) there are contained, kilogrms. per *tan*:

	Total ash.	Potash.	Phosphoric acid.	Lime.	Magnesia.
Lucerne ...	...49.6	11.58	4.24	20.16	2.48
Clover... ...	...34.6	11.16	3.36	12.06	3.78

Hagi extracts, therefore, rather less from the soil than either lucerne or clover, and as its roots grow to a greater depth and thus avail themselves of a larger volume of soil than those of the two latter crops, we may anticipate that a field will yield, like lucerne in some cases, a satisfactory quantity of fodder for a long succession of years.

As the composition of feeding stuffs, as shown by the chemical analysis, does not fully suffice for an exact judgment on the nutritive value, we carried out a *digestion experiment* with two sheep, and used for this purpose the hay obtained in the first cutting of 1889. About 40 kilogrms. of this hay which had been stored in a dry room during the summer, were cut into pieces of about 2 centimetres' length and well mixed, before the experiment commenced. The two animals, rams of the Southdown breed about 2½ years old, furnished with bags of rubber cloth and with rubber funnels to guide the urine off into a bottle, were kept during the whole experiment in the feeding boxes described in Bulletion No. 2, p. 2—5. From November 5th—18th they received 1 kilogrm. of the hay per day per head, besides water ad libitum and 6 grms. of common salt. After 6 days preliminary feeding the residues of food left uneaten and the fæces were quantitatively collected and the amounts of water consumed and of urine excreted determined. Besides this, the animals were weighed every morning. The results of these determinations were the following:

Date.	Hay left uneaten.		Water consumed.		Live-weight. kilograms.	
November.	Sheep No. I. grms.	Sheep No. II. grms.	Sheep No. I. grms.	Sheep No. II. grms.	Sheep No. I.	Sheep No. II.
11th	208	166	1100	1210	26.9	29.5
12 ,,	173	21	1290	1200	26.9	29.3
13 ,,	205	24	1200	1670	27.0	29.5
14 ,,	207	25	1120	1260	27.1	29.6
15 ,,	164	6	1280	1620	27.1	29.8
16 ,,	152	6	1390	1560	27.4	30.0
17 ,,	157	5	1620	1530	27.6	30.2
Daily average	180.8	536.14	1286	1436	—	—

Date.	Fæces.		Urine.	
	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
November.	grms.	grms.	grms.	grms.
11th	870	1099	482	552
12 ,,	972	1092	410	583
13 ,,	962	1156	422	579
14 ,,	934	1010	404	532
15 ,,	899	1152	423	463
16 ,,	1043	1277	490	510
17 ,,	1139	1153	460	473
Daily average	974.1	1134.1	441.6	527.9

The residues of hay left by the animals consisted for the most part of the lower coarse stems of the plants; the whole quantity was dried and powdered for the analyses. Of the fæces, after well mixing them, every day one tenth of the whole amount was weighed out for the analyses and treated as usual.[5]

The composition of the food, residues, and fæces is shown by the following figures:

		Residues.		Fæces.	
	Hay	Sheep No. I.	Sheep No. II.	Sheep No. I.	Sheep No. II.
Water	16.76 %	22.20 %	19.26 %	63.68 %	64.67 %
In the dry matter:					
Crude protein.	19.89 %	9.62 %	13.77 %	18.05 %	15.30 %
,, fat ...	3.09 ,,	1.43 ,,	1.97 ,,	3.25 ,,	2.66 ,,
,, fibre ...	39.78 ,,	57.12 ,,	48.91 ,,	38.91 ,,	37.96 ,,
Nitrogen-free extract	32.32 ,,	27.78 ,,	30.70 ,,	32.89 ,,	38.53 ,,
Ash	4.92 ,,	4.05 ,,	4.65 ,,	6.90 ,,	5.55 ,,

From all these data the daily consumption, excretion, and digestion of each single component of the food is calculated in the following table:

5 Further particulars about the methods applied in digestion experiments and the mode of calculating the results see in Bulletin No. 2, p. 3—6.

	Dry matter. grms.	Organic matter. grms.	Crude protein. grms.	Fat. grms.	Fibre. grms.	Nitrogen-free extract. grms.
SHEEP No. I.						
Hay given	832.40	791.45	165.57	25.72	331.12	269.04
,, left	140.70	135.00	13.54	2.01	80.37	39.08
,, consumed ..	691.70	656.45	152.03	23.71	250.75	229.96
Excreted (fæces) ..	353.83	329.42	63.87	11.50	137.67	116.38
Digested	337.87	327.03	88.16	12.21	113.08	113.58
Digested, per cent of each component	48.83	49.82	57.99	51.50	45.10	49.39
SHEEP No. II.						
Hay given	832.40	791.45	165.57	25.72	331.12	269.04
,, left	29.17	27.81	4.02	0.57	14.27	8.95
,, consumed ..	803.23	763.64	161.55	25.15	316.85	260.09
Excreted (fæces) ..	400.61	378.38	61.29	10.66	152.07	154.35
Digested	402.62	385.26	100.26	14.49	164.78	105.74
Digested, per cent of each component	50.12	50.45	62.06	57.61	52.00	40.66
Digestion-coefficients, average of the two animals	49.48	50.14	60.03	54.56	48.55	45.03

According to these results the digestibility of the *hagi* hay is lower than that of most other leguminous forage crops. For comparison we may quote the following digestion-coefficients from E. von Wolff's compilations:

	Organic matter.	Crude protein.	Crude fat.	Crude fibre.	Nitrogen-free extract.
Clover, medium good ...	56.8	54.6	50.9	44.9	65.0
Lucerne ,, ,, ...	55.9	69.9	38.9	41.9	63.3
Esparsette, very good ...	62.1	69.9	66.2	36.4	74.3

In order to get a more digestible fodder from *hagi* it will be advisable to take the first and second cuttings earlier than we did, because it appears that the formation of woody fibre proceeds very rapidly just before the buds make their appearance. By early curing the yield of hay in the first two cuttings will, of course, be somewhat lower than in our trials, but this diminution will be compensated by the better quality and digestibility of, as well as by a larger yield in, the third cutting. As we intend to continue our researches on this plant, we will pay due attention to these conditions.

The hay of *hagi* as compared with that of other leguminous forage crops contained according to the above feeding experiments the following proportions of digestible nutrients, per cent of the air-dry matter:

	Crude protein.	Carbo-hydrates.	Crude fat.	Nutritive ratio.
Hagi	9.9	28.2	1.4	3.2
Lucerne, medium good...	9.4	28.3	1.0	3.3
Red clover, ,, ,, ...	7.0	38.1	1.2	5.9
Soy bean...	9.1	36.5	0.4	4.1

The low digestibility of *hagi* hay is accordingly entirely compensated by its richness, so that from a practical point of view its nutritive value is equal to that of medium good lucerne hay and nearly as good as soy bean hay (*karimame*) cured when the pods have completely developed, while it is distinctly superior to that of medium good clover hay.

A calculation of the annual yield of digestible matter per *tan*, based on the preceding figures, gives the following results:

	Crude protein. kilogrms.	Carbo-hydrates. kilogrms.	Crude fat. kilogrms.
Hagi, 1887	67.2	222.1	16.0
,, 1889...	73.2	218.5	15.3
,, 1890...	70.7	287.0	11.0
Lucerne	75.2	226.4	8.0
Red clover	42.0	288.6	7.2

It should be kept in mind that the produce quoted for lucerne and clover represents the medium amount obtained in central Europe, and that in Japan where the winter is shorter, it will certainly be somewhat larger. Making due allowance for this, the yield of digestible nutrients in the *hagi* crop still compares favorably with that of the other forage plants of the same family.

Since 1888 another variety, Lespedeza bicolor, ~~Turcz.~~, var. Sieboldi, Maxim., ~~known as~~ (*natsu hagi*) has been cultivated by us. Roots of it were planted early in the spring of 1888 on a plot adjoining that of the variety intermedia, and threw up a considerable number of shoots, which attained a height of about 0.8 metre and were cut off in the following winter. In 1889 and 1890 three cuttings taken from this plant gave the following results:

	Green fodder. kilogrms.	Hay. kilogrms.
1889		
1st cutting, May 24th	918.2	227.3
2nd ,, July 19th	487.3	145.8
3rd ,, October 14th	301.8	118.3
Total	1707.3	491.4
1890		
1st cutting, June 14th	658.1	207.0
2nd ,, September 10th	948.0	309.4
3rd ,, November 13th	63.7	22.5
Total	1669.8	538.9

The yield of hay produced by *natsu hagi* is accordingly considerably smaller than that of common *hagi* and does not equal a medium crop of clover in central Europe. Such a result was to be anticipated as this plant is much smaller than the other variety of Lespedeza.

The analysis of the crop of 1889 gave the following results:

	Water. %	Crude protein. %	Crude fat. %	Crude fibre. %	Nitrogen-free extract. %	Ash. %
Green fodder.						
1st cutting...	79.21	3.92	0.89	5.86	9.08	1.04
2nd ,, ...	74.09	4.52	0.79	9.01	10.09	1.50
3rd ,, ...	65.68	6.87	1.78	10.57	13.28	1.82
Hay.						
1st cutting...	16.03	17.78	4.00	26.47	31.02	4.70
2nd ,, ...	13.41	15.09	2.65	30.11	33.74	5.00
3rd ,, ...	12.46	17.55	4.54	26.98	33.83	4.64
Dry matter.						
1st cutting...	—	21.17	4.76	31.52	36.95	5.60
2nd ,, ...	—	17.43	3.06	34.77	38.96	5.78
3rd ,, ...	—	20.04	5.18	30.81	38.67	5.30

Of the nitrogen present in the dry matter, the following quantities were found to exist in the form of albuminoid and non-albuminoid:

	1st cut	2nd cut	3rd cut
Total nitrogen	3.387	2.788	3.207
Albuminoid nitrogen ...	2.836	2.480	2.831
Non-Albuminoid nitrogen	0.551	0.378	0.376
,, , per cent of the total nitrogen	16.2	11.0	11.7

The yield of single nutrients contained in the crop of 1889 is illustrated in the following table, kilogrms. per *tan*:

	Dry matter.	Organic matter.	Crude protein.	Crude fat.	Crude fibre.	Nitrogen-free extract.	Ash.
1st cutting...	190.9	180.2	40.4	9.1	60.2	70.5	10.7
2nd ,, ...	126.3	119.0	22.0	3.9	43.9	49.2	7.3
3rd ,, ...	103.6	98.1	20.8	5.4	31.9	40.0	5.5
Total...	420.8	397.3	83.2	18.4	136.0	159.7	23.5

From these figures we find the composition of the whole crop of 1889 to have the following percentage composition:

	Hay.	Dry Matter.
Moisture	...14.36	—
Crude protein	...16.93	19.77
,, fat	... 3.74	4.37
,, fibre	...27.68	32.32
Nitrogen-free extract	...32.50	37.95
Ash	... 4.79	5.59

The hay of *natsu hagi* is accordingly a little richer in crude protein and poorer in fibre, and will therefore have a higher digestibility than that of the other variety. This slightly better quality of the fodder from the former plant does not, however, compensate for the lower yield. Hence if the choice is left between the two species, the common *hagi* is preferable especially as also in other respects the *natsu hagi* does not offer any advantages.[6]

6 While compiling the results of the above experiment, I notice in "Experiment Station Record," vol. 2, No. 4, (November 1890), p. 164, published by the Office of Experiment Stations in the United States' Department of Agriculture, an abstract of a report on "*Japan clover—its value as a renovator of worn soils* by G. McCarthy," contained in bulletin No. 70, April 15th, 1890, p. 24—27, of the North Carolina Experiment Station. The abstract runs thus: "Japan clover (Lespedeza striata) is described and illustrated, the conditions favorable to its growth are stated, and its usefulness as a renovator of worn-out soils, through its ability to collect nitrogen from the air and soil, is urged. It is also recommended as affording excellent pasturage for animals, especially sheep.—'"In the spring of 1889 experimental plats of Lespedeza and all the common clovers were sown on the North Carolina experiment farm. The soil was a very poor, stiff clay. The only fertilizer applied was a light dressing of phosphate at the time of sowing the seed. All the true clovers, lucerne, and serradella did very poorly, but the plat of Lespedeza presented a most luxuriant appearance throughout the season. While all the other plats were more or less infested with crab grass and weeds, not a weed, nor a blade of grass could be found in the Lespedeza plat."'—North Carolina farmers are recommended to sow Japan clover in fields which are now unproductive, and by this means secure pasturage for sheep, and at the same time increase the fertility of the soil."

We may add that Lespedeza striata Hook. et Arn., is an annual species occurring throughout the main island of Japan in two varieties known as *yahazu sō* and *maruba yahazu sō*. Experiments in its cultivation were made

A few more words may be added regarding the mode of cultivating and curing *hagi*. If roots are at hand on uncultivated land, they may be collected towards the end of winter and planted at distances of 8—10 inches, a month or two after the field has received a dressing of slaked lime, 25—50 *kuwamme* per *tan*. This manner of cultivation is particularly preferable, if the field for *hagi* is newly broken land liable to be infected by the seeds of weeds, or on which the remains of preceding plants would oppress the tiny seedlings developing from *hagi* seeds. Some observations of ours seem also to show that strong *hagi* plants develop from the woody stems, if the latter are cut at the close of the winter and completely buried in a horizontal position in the soil about 2 inches deep. On land free from weeds *hagi* can be well raised from seeds collected in November or December. The seeds of this plant are, however, very hard, and after being sown resist the entrance of moisture so strongly that the germination is very irregular and, with many seeds, takes place not before 5—15 months. It is therefore advisable to put the seeds together with a 2—3 fold volume of coarse sand into a strong bag and to strike the latter vigorously with a heavy stick in order to scratch the cuticle of the seeds. By such treatment the absorption of water is facilitated and regular germination ensured. Anyhow,

---

last year in our farm on behalf of Mr. *S. Harada*, a graduate of the college now on the staff of the Imperial Department of Agriculture and Commerce, who recorded the results of the trial in the Official Gazette (Tōkyō) of December 9th, 1890. The seeds were sown on May 2nd in rows of 12 inches distance after the application of some superphosphate, bone dust, and straw ash. *Yahazu sō* was cut on the 5th, *maruba yahazu sō* on the 20th of September. There was obtained, kilograms per *tan*:

	Green fodder.	Hay.
Yahazu sō	..1269.2	320.3
Maruba yahazu sō	..1485.5	351.9

The yield is accordingly far inferior to that obtained in our experiments with *hagi*, but may be certainly somewhat increased by sowing broad-cast. Judging from the appearance of the two varieties, their percentage content of digestible nutrients will be larger than that of *hagi*.

the quantity of seeds must not be too small, and sowing broadcast is best. The development of the plants from seeds is very slow at first, but from July their growth seems to be suddenly stimulated, and by the beginning of September the stems attain a height of 1—1.5 metres. At that time the first cutting may be taken and the second one towards the end of October or at the beginning of November before the occurrence of frost. In the subsequent years the plants may be cut 3—4 times annually. Lime, wood ashes, or straw ashes are suitable as manure, and may be applied in large doses in the winter every 3—4 years.—In curing the plants for hay care must be bestowed on the manner of drying, to avoid loss of leaves which easily break off while turning the plants, and constitute just the most nutritious part of the fodder. The application of pyramides made of raw wooden staffs on which the plants are suspended, deserves to be recommended.

In general, our experiments have shown that *hagi* is a very valuable forage crop, especially for cattle farms established on uncultivated land (hara) where there is at present insufficient nutrition for the animals during winter, and where manures for more pretentious plants are not available. Its cultivation should likewise be attended to in all those places (waste land, road sides, embankments of rail roads, etc.) from which plants are taken for feeding or manuring purposes. Owing to the capacity of *hagi* for assimilating free nitrogen from the air, not only is good fodder and manure rich in nitrogenous substances produced, but the soil is also improved and gradually prepared for the future cultivation of more remunerative crops.

ERRATA

In Bulletin No. 8.

Page 5, 3rd line from top, read *far* instead of *for*.
,, 9, 12th line from top, read 16 bundles, each of 15 healthy......, instead of 16 bundles of healthy......
,, 10, 14th line from top, read taken out and photographed, instead of taken out.
,, 18, table, read in the 6th and 7th columns kuwamme, instead of kilogrms.
,, 19, table, read in the 6th and 7th columns kuwamme, instead of kilogrms; and in the 8th and 9th columns read koku, instead of kuwamme.
,, ,, table, read in the V. Series under 3), 40 kilogrms. lime, instead 10 kilogrms.
,, 25, table, 6th line, read 25 kilogrms., instead of 45 kil.
,, 28, heading of the table, 5th column, read 7.5, instead of 7.6
,, 32, 10th line from bottom, read 5—15, instead of 5—25.
,, 35, 10th line from top, read 7.542, instead of 8.542.
,, 38, Plot No. 11, read 20 kil. K_2O, instead of 30 kil. K_2O.

農科大學
學術報告
第十號

IMPERIAL UNIVERSITY.

College of Agriculture.

(FORMERLY IMPERIAL COLLEGE OF AGRICULTURE AND DENDROLOGY).
KOMABA, TŌKYŌ, JAPAN.

BULLETIN NO. 10.

Manuring Experiments with Paddy Rice.
(Second Year.)

Communicated

BY

DR. O. KELLNER,

Professor of Agricultural Chemistry.

明治二十四年六月

TŌKYŌ, KOMABA, JUNE, 1891.

PRINTED BY HAKUBUNSHA, GINZA, TŌKYŌ

Manuring Experiments with Paddy Rice.
(Second Year, 1890.)

BY

Dr. O. Kellner, Y. Kozai, Y. Mori, and M. Nagaoka.

The principal purpose of the researches carried out by us in 1889 and reported in bulletin No. 8 was to ascertain how much nitrogen, phosphoric acid, and potash can be consumed by rice from the stock of nutrients in the unmanured soil, and how much of them is needed in the manure for the production of a maximum crop if the three nutrients are applied in the most assimilable form. On the basis of the results then obtained, we partly continued in 1890 these experiments, partly we tried new ones, with the object of getting information on the following questions:

I. How much nitrogen, phosphoric acid, and potash is taken up from those plots which had not received the respective nutrients in the preceding year?

II. What is the effect of unrecovered phosphatic manure on the succeeding crop?

III. How much nitrogen can be supplied to rice by the preceding cultivation of a leguminous plant (Astragalus lotoides, Lam.) for green manuring?

IV. What is the effect of various phosphatic fertilizers on rice?

V. What is the effect of various nitrogenous manures on rice?

The arrangement of the experimental plots was the same as

in the preceding year. Wooden frames 2 feet high and 3 feet square were sunk into the well mixed soil up to an inch from the upper edge, and each of them was furnished on the northern side with a tank of a capacity of about 70 litres from which each plot was separately irrigated. As to the composition of the soil and water, reference may be made to bulletin No. 8 (p. 3-5). The variety of rice was that most commonly used by the farmers in the neighbourhood and known as *shiratama*, which has a medium length of vegetation. Each frame received on the 23rd of June 16 bundles each of 12 healthy plants which had been raised in a seed bed. Compared with the experiments of 1889 the plants mere in a more advanced state of development containing in 1000 individuals 326.3 grms. of dry matter against 85.6 grms. in the preceding year. The manures were incorporated with the soil several days before transplanting; the potassic and phosphatic manures being given first, and 2 days afterwards the nitrogenous fertilizers. Due care was, of course, taken to allow the fertilizers to be absorbed by the soil before the transplantation and irrigation were commenced. The weather was extremely favorable to rice throughout the reason, and no injuries were noticed either from insects, or from fungi except from smut, which destroyed, however, per plot only 3-8 grains and was observed only on 9 plots. Towards the end of September the irrigation was discontinued, and water was given only for two days, as usual when the rice was in blossom. The crop was harvested on the 1st and 2nd of November when the plants were ripe. The plants were dried in the sun, and when they were air-dry, we weighed the straw, total grain, and hulls, which had not been fertilized. Of each of the products weighed samples were kept for analysis.

Each trial was carried out in triplicate.

I. Series.

HOW MUCH NITROGEN, PHOSPHORIC ACID, AND POTASH IS TAKEN UP FROM THE SOIL ON THOSE PLOTS ON WHICH RICE HAD ALREADY BEEN CULTIVATED IN THE PRECEDING YEAR WITHOUT THE APPLICATION OF THESE NUTRIENTS?

In this series we intended to ascertain whether the consumption of nutrients by the first crop reduces their stock so far that the succeeding crop finds appreciably less in the soil, or whether the natural decomposition of the soil constituents during the winter and spring supplies fresh nutrients to the crop. The series comprised 15 plots which were manured as follows:

1) 3 plots were left unmanured.
2) 3 ,, did not receive any nitrogenous manure, but were supplied with much phosphoric acid (22 kilogrms. per *tan*[1]) and (11 kilogrms.) potash.
3) 3 plots received a manure free from phosphoric acid containing much (11 kilogrms.) nitrogen and (11 kilogrms.) potash.
4) 3 plots were not supplied with potash, but received much (22 kilogrms.) phosphoric acid and (11 kilogrms.) nitrogen.
5) 3 plots received a complete manure containing 11 kilogrms. nitrogen, 22 kilogrms. phosphoric acid, and 11 kilogrms. potash.

In all these experiments the nitrogen was applied as ammonium sulphate, the phosphoric acid as sodium phosphate, and the potash as carbonate.

The best development took place on the plots which had received all three nutrients; compared with these the plants without potash were only slightly inferior; next in order of

1) 1 *tan*=0.0992 hectare; 1 *koku*=180.39 litres.

vigor and height were those without nitrogen, which turned, however, pale an at early period of growth and ripened about 10 days before all the other plots; the plants without phosphoric acid and those without any manure represented essentially the same appearance, remaining very small, with a dark green colour, and exhibiting less inclination to ripen.

The yield of grain and straw of the single plots will be found in the appendix. In the average of three equally manured plots we obtained the following produce:

	Straw. grms.	Full grain. grms.	Empty grain. grms.	Whole crop. grms.
Unmanured	325	277.0	2.1	604
Without nitrogen...	536	412.7	3.2	952
,, phosphoric acid	358	260.9	2.6	622
,, potash	770	582.5	8.2	1361
With complete manure	975	638.1	7.6	1621

In their general features these results coincide very well with those obtained in the preceding year, as is demonstrated in the following table which gives the yield of dry matter in grms. per plot:

	Straw.	Full grain.	Empty grain.	Whole crop.
1889.				
Unmanured	166	90.5	5.7	262
Without nitrogen	386	314.6	13.5	714
,, phosphoric acid.	162	76.3	5.7	244
,, potash	609	481.9	21.0	1049
Complete manure[2]	716	543.3	25.3	1285
1890.				
Unmanured	285	238.3	1.9	525
Without nitrogen	436	356.2	2.8	795
,, phosphoric acid.	302	229.5	2.3	534
,, potash	616	497.3	7.2	1120
Complete manure	771	543.3	6.7	1321

2 Average of plots Nos. 5, 17, and 24 of 1889.

It may thus be seen that among the three important ingredients of plant-food the phosphoric acid exists in our soil in the minimum, and that a supply of nitrogenous and potassic fertilizers without the simultaneous application of phosphates does not materially increase the yield over that obtained without any manure. The stock of nitrogenous nutrients in the soil sufficed, however, for a considerable development of the rice, when a fair amount of phosphoric acid was provided for in the manure; yet the addition of nitrogen to the soil had a further very marked effect. As to the stock of potash in the soil, both years' experiments prove that it does not quite suffice for a maximum crop, and that a slight addition of it to the manure distinctly increases the yield.

With regard to absolute produce of grain and straw, some differences are noticed between the two years, particularly as regards the unmanured plots and those which had not been supplied with phosphatic manure. A close coincidence could not, of course, be anticipated, as the variety of rice was not the same, and the meteorological conditions differed, those of 1890 being extremely favourable, those of 1889 less suitable to rice. The chief reason for the differences between the two years is, however, the different condition of the plants raised in the seed bed. In 1889, 240 plants were used for each plot, in 1890 only 182, and in these plants there was contained:

	1889.	1890.
Dry matter	20.55 grms.	62.66 grms.
Nitrogen	0.366 ,,	1.774 ,,
Phosphoric acid	0.087 ,,	0.334 ,,
Potash	0.192 ,,	0.653 ,,

The far larger amount of phosphoric acid and nitrogen in the plants of 1890 secured, of course, a better development especially on those plots which did not receive these nutrients in the manure.

We have next to consider—how far is the soil exhausted by the crops of the two successive years? First referring to the consumption of *nitrogen* we found the following results:

		Nitrogen in the dry matter of the whole crop.		Nitrogen in the manure.	Nitrogen extracted from the soil resp. from the soil and manure.
		%	grms.	grms.	grms.
Unmanured,	1889	...1.435	3.84	0	3.47
,,	1890	...1.078	5.66	0	3.89
Without nitrogen,	1889	...1.054	7.54	0	7.17
,, ,,	1890	...0.937	7.43	0	5.66
Complete manure,	1889[3]	...1.096	13.37	9.18	13.00
,, ,,	1890	...0.943	12.46	9.18	10.69

The results obtained on the plots without nitrogenous manure give evidence that the exhaustion of the soil by the plants of 1889 involved a smaller supply of nitrogen to the succeeding crop. While the former consumed 7.17 grms. of nitrogen, the latter took up only 5.66 grms. The diminution of the stock of assimilable nitrogen caused by the crop of 1889 was accordingly not completely compensated by the subsequent decomposition of organic nitrogenous soil ingredients during the winter and spring 1889—90. Nevertheless, the conversion of nitrogenous matter previously unfit for the nutrition of rice, into assimilable compounds during the interval between the two crops was not insignificant. Assuming the assimilable ingredients to exist in the form of ammoniacal compounds from which rice is enabled, according to our researches, to consume 62.2 %, the soil must have contained per *tan* in 1889 13.85[4] kilogrms. of available nitrogen. As from this quantity 7.82 kilogrms. were actually consumed by the plants, only 6.03 kilogrms. were left for the succeeding crop, and from this amount only 3.02 kilogrms. could enter the plants. In the crop of 1890 we found, however, 6.79 kilogrms., hence 3.77 kilogrms. came from natural sources. Assuming this quantity to have also been taken up from

---

3 Average of plots 3, 15, and 22 of 1889.

4 In bulletin No. 8 erroneously stated to be 12.57 kilogrms.

ammoniacal compounds, the supply of nitrogen rendered available by decomposition in the soil or imparted to the field by rain and irrigation must have amounted in 1890 to 6.06 kilogrms. per *tan*. As our soil is exceptionally rich in nitrogenous organic compounds, while the water used for irrigation and the rain are poor in nitrogen, we may conclude that the greater part of the above amount was yielded by the soil, and that under other conditions, on soils poor in humus, the supply of nitrogen by decomposition will fall considerably below the above quantity.

The content of nitrogen in the crop of the two unmanured plots (3.47, resp. 3.89 grms.) was in 1890 a little larger than in 1889, owing to the presence of more phosphoric acid in the young transplanted rice, which enabled them to consume and work up more of the available nitrogen of the soil.

Of the nitrogen applied as ammonium sulphate to the plots with complete manure the following proportions were taken up in the two seasons:

Nitrogen	1889.	1890.
In the whole crop	13.37 grms.	12.46 grms.
In the crop grown without nitrogen	7.54 "	7.43 "
Taken up from the manure ...	5.83 "	5.03 "
Applied in the manure	9.18 "	9.18 "
Taken up, per cent of the nitrogen applied	63.0 "	54.8 "

In the favourable season of 1890 the rice consumed less nitrogen from the manure, but produced with it a larger proportion of organic matter than in 1889, as is demonstrated by the lower percentage content of nitrogen in all the above crops of 1890.

Turning now to the consumption of *phosphoric acid* by rice, our analysis gave the following results:

		Phosphoric acid in the dry matter of the whole crop.		Phosphoric acid in the manure. grms.	Phosphoric acid taken up from the soil, resp. from soil & manure. grms.
		°/o	grms.		
Unmanured,	1889...	...0.240	0.64	0	0.55
,,	1890...	...0.165	0.86	0	0.53
Without phosphoric acid,	1889...	...0.232	0.61	0	0.52
,,	1890...	...0.165	0.88	0	0.55
Complete manure,	1889[5]	...0.320	4.12	18.36	4.03
,,	1890...	...0.206	2.73	18.36	2.40

It may thus be seen that the quantity of phosphoric acid taken up from the unmanured plots and from those which had not received phosphatic nutrients showed only slight fluctuations in the two seasons. There is in this fact clear evidence that the exhaustion induced by the first crop was almost exactly compensated by the fluxation of phosphatic material formerly inaccessible to the plants. A calculation made in the same way as in the case of nitrogen shows that by decomposition of soil ingredients 0.7 kilogrms. had been added per tan to the stock of available phosphoric acid left unexhausted by the preceding crop.

There is, on the other side, a considerable difference between the seasons in regard to the consumption of the liberal dose of phosphoric acid given in the complete manure, as is demonstrated in the following calculation :

Phosphoric acid, grms.

	1889.	1890.
In the whole crop	4.12	2.73
In the crop grown without phosphoric acid	0.57	0.88
Taken up from the manure	3.55	1.85
Applied in the manure	18.36	18.36

5 Average of plots 30, 40, and 45 of 1889.

	1889.	1890.
Taken up, per cent of the phosphoric acid applied	19.4	10.1

Thus, while in the unfavourable season of 1889 almost 20 % was taken up by the plants, only half that amount was consumed in the succeeding year. It is very probable that this difference may be accounted for by the conditions of heat and light which accelerated in 1890 the maturity of the rice and thus rendered impossible any considerable surplus consumption of phosphoric acid. The lower percentage content of this nutrient in the dry matter produced this season, at least intimates that there was a surplusage of phosphoric acid in the crop of the preceding year.

Lastly, as to the consumption of *potash* from the soil, we obtained the following results :

		Potash in the dry matter of the whole crop.		Potash in the manure.	Potash taken up from the soil, resp. from the soil and manure.
		%	grms.	grms.	grms.
Unmanured,	1889	...0.705	1.89	0	1.70
,,	1890	...0.886	4.65	0	4.00
Without potash,	1889	...0.429	4.78	0	4.59
,, ,,	1890	...0.386	4.32	0	3.67
Complete manure,	1889[6]	...0.710	9.25	9.18	9.06
,, ,,	1890	...0.770	10.17	9.18	9.52

The plants supplied with nitrogen and phosphoric acid, but left without potassic manure, did not find so much potash in 1890 as in the preceding season, although in the latter season the consumption of this nutrient appears to have been specially favoured, as is illustrated by the results on the unmanured plots and on those which had received a complete manure. Doubtless, the exhaustion of potash was in 1889 so great that

6 Average of plots 48, 58, and 73 of 1889.

the assimilable residue left, together with that potash which newly became available by decomposition and irrigation, did not suffice to yield to the crop as much of this nutrient as in the preceding season. A calculation made in the same way as in the case of the nitrogen consumption, shows that the available residue after the first crop amounted to 4.59 grms. per plot, from which the plants could take up only (50 %) 2.30 grms. As they actually absorbed 3.67 grms., only as much as 1.37 grms. were contributed by ingredients newly rendered available and by irrigation. The whole increase of available potash during the period of one year amounted accordingly to only 2.74 grms. per plot=3.3 kilogrms. per *tan*, a quantity which would not suffice for rice for any successive years unless some potash were supplied in the manure.

An account of the proportion of ***potash*** absorbed by the crop from the manure is given in the following table:

	Potash, grms. 1889.	Potash, grms. 1890.
In the whole crop...	9.25	10.17
In the crop grown without potash	4.78	4.32
Taken up from the manure	4.47	5.85
Applied in the manure	9.18	9.18
Taken up, per cent of the potash applied ...	48.7	63.7

Thus, in 1890 the crops consumed more potash from the manure than in 1889, and this is principally explained by the difference of the two seasons. High maturation, such as took place in 1890, is generally associated with a high proportion of potash in the crop. This fact was also noticed by J. H. Gilbert[7] in long continued experiments on the growth of barley at Rothamsted; comparing the contents of nitrogen, phosphoric acid, and potash, Gilbert writes: "Whilst in the case of potash there is the higher proportion in the better seasons, in that of phosphoric acid there are lower amounts in the dry

7 Results of Experiments at Rothamsted, on the Growth of Barley. Agr. Students' Gazette, vol. III, part II. (Reprint p. 19.)

substance in the better seasons. In fact high amount of potash in the ash and in the dry substance of the grain, is as a rule associated with high maturation, that is with high proportion of starch, whilst high proportion of phosphoric acid is generally associated with low maturation and high proportion of nitrogen." Our observations on the growth of rice fully coincide with these remarks.

To sum up the results of the two years' experiments on rice, it may be stated:

1) that through decomposition of soil ingredients and through irrigation, in the case of nitrogen also through rain and fixation from the air, there was rendered available to the crop in the course of one year per *tan*:

6.1 kilogrms. of nitrogen,
0.7 ,, ,, phosphoric acid, and
3.3 ,, ,, potash.

2) In the better season of 1890 the exhaustion of the nitrogenous and phosphatic fertilizers was less, that of potash higher than in the preceding year, in which maturation was less complete.

II. Series.

WHAT IS THE EFFECT OF THE UNRECOVERED PHOSPHORIC ACID ON THE SUCCEEDING CROP?

These experiments were carried out on those plots which had received in 1889 various quantities of phosphoric acid in the form of sodium phosphate, besides much nitrogen as ammonium sulphate and much potash as carbonate. In order to ascertain how much of the phosphoric acid left by that crop in the soil was still available in the second season, we applied in 1890 per *tan* 11 kilogrms. of nitrogen as ammonium

sulphate and 11 kilogrms. of potash as carbonate, but did not add any phosphoric manure. For the sake of comparison we may here also take into account the plots without phosphoric acid (p. 4) and those which in 1889 were left unmanured, but again received in 1890 a complete manure containing per *tan* 22 kilogrms. of phosphoric acid as sodium phosphate besides much nitrogen and potash. The quantities of phosphoric acid used in the former season and the proportions left in the soil by that crop, as well as the produce in the second season are recorded in the following table :

Phosphoric acid applied per plot in 1889. grms.	Phosphoric acid not recovered in the crop of 1889.		Straw. 1890. grms.	Full grain 1890. grms.	Empty grain. 1890. grms.	Whole crop. 1890. grms.
	grms.	kilogrms. per *tan*				
0	—	—	358	260.9	2.6	622
4.59	3.65	4.38	350	272.9	2.5	625
9.18	6.99	8.39	362	269.4	3.5	635
13.77	10.86	13.04	500	411.8	0.9	913
18.36	14.81	17.77	589	480.6	2.4	1072
22.95	19.32	23.18	722	524.1	7.9	1254
27.54	23.29	27.95	707	587.3	8.5	1303
0	18.36[8]	22.03[8]	975	638.1	7.6	1621

The two lowest quantities of phosphoric acid (4.59 and 9.18 grms.) applied in 1889, of which only 20.5, resp. 22.8% had been consumed by the crop of that year, were accordingly without any effect on the crop of 1890, whereas the residues from larger doses (13.77—27.54 grms.) produced a distinct increase, which, however, with as large a proportion as 23.29 grms. of residual phosphoric acid, did not come up to the maximum yield obtained with 18.36 grms. of freshly applied

8 Applied in 1890; average of plots 12, 36, and 65.

phosphoric acid. Similar results were arrived at in the determination of the amount of phosphoric acid that was taken up by the plants from the residues in the soil, as is shown by the following figures :

Phosphoric acid, grms.	1.	2.	3.	4.	5.	6.	Freshly manured.
In the whole crop of 1890	0.84	0.86	1.36	1.71	2.11	2.44	2.73
In the crop of 1890 produced without phosphoric acid ..	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Consumed from the residual phosph. acid left by the crop of 1889	—	—	0.48	0.83	1.23	1.56	1.85
Residue of phosphoric acid from 1889 ..	3.65	6.99	10.86	14.81	19.32	23.29	18·36
Consumed, per cent of this residue ..	—	—	4.42	5.60	6.37	6.70	10.06

Thus, the residues left from the two smallest doses of phosphoric acid were no longer available at all to the subsequent crop, while from the unexhausted portions of larger doses, considerable quantities were assimilated. But the freshly applied phosphate was distinctly more accessible to the plants than the residues left from the preceding year.

In these facts there is clear evidence that some of the residual phosphoric acid must have either been washed away by irrigation or rain, or have assumed a state in which it could no longer be dissolved by the roots or agencies in the soil. Without denying that both these processes may have taken place, several facts appear to indicate that the conversion into an insoluble state was the principal cause of the inaccessibility to the roots of the residual phosphate. Indeed, when sodium phosphate is incorporated with a soil so rich in hydrated sesquioxides of iron and alumina as ours, the greater part of the phosphoric acid at once yields basic phosphates with these

sesquioxides which are known to be of inferior effect on crops; and those portions which remain in a more soluble form, become through the same chemical process likewise less and less assimilable in the course of time. Compounds of the character of bog iron, to the formation of which our soil is greatly inclined, no longer yield to the plants the phosphoric acid deposited in them. The comparative experiments on the effect of various phosphates on rice to be described later on, will give further evidence that processes of this kind are actually accomplished in our soil.

The changes of the solubility of phosphates in soils are dependent on two factors, the character of the phosphate applied and the condition of the soil. Owing to its great solubility in water, the sodium phosphate among the common phosphates, certainly yields most easily its acid to the basic compounds of the soil, and, from this point of view, the results obtained with it are also valid for the phosphates of ammonium or potash recently manufactured in Europe for manuring purposes. On ferruginous soils poor in lime such phosphates will certainly have less effect than dicalcium phosphate, Thomas phosphate, etc., and may even prove to be inferior to superphosphate. This point will be further referred to in a later part of this paper.

The capacity of a soil for rendering soluble phosphates inaccessible to the roots is, of course, limited; and if various quantities of such fertilizers are mixed with equal volumes of soil, the conversion into insoluble forms will be more complete with the small than with the large doses. This is clearly intimated in our experiments by the progressive quantities consumed from the residual phosphoric acid; the larger the amount of the residue, the higher was its percentage exhaustion by the subsequent crop. We may indeed deduce from the figures in the above table that in all the six trials on the assimilability of residuary phosphoric acid, an equal proportion, about 5.7 grms. per plot, entirely lost the capacity of being consumed by the plants. If we deduct this quantity in each

trial from the total residuary nutrient, and calculate how much in 100 parts of the amount thus found was consumed by the crop, we obtain the following figures:

No. 3.	No. 4.	No. 5.	No. 6.
9.3 %	9.1 %	9.1 %	9.0 %

The close coincidence between these results justifies our assumption that about 6.5 kilogramms of phosphoric acid per *tan* had become entirely unfit for the nutrition of rice.

III. Series.

HOW MUCH NITROGEN CAN BE SUPPLIED TO RICE BY THE PRECEDING CULTIVATION OF A LEGUMINOUS PLANT (ASTRAGALUS LOTOIDES, LAM.) AS GREEN MANURE?

Astragalus lotoides Lam., in Japan, commonly known as *genge*, is cultivated in several districts as green manure for rice. It is usually sown between the rice plants in September or October, when irrigation is discontinued, and in the succeeding year about the beginning of May attains the flowering stage, when it is dug into the field on which it was raised. As leguminous plants unlike others, have the peculiar faculty of assimilating free nitrogen from the air, this practice has for its object an accumulation of nitrogen in the field, and consequently a reduction of the amount of nitrogenous manure otherwise required. As it was not known how much nitrogen is gained by a successful culture of this plant, or whether, besides the green manure, other nitrogenenous fertilizers are needed for the rice, experiments had been commenced as early as 1889, but the time for sowing (April) was then past, and when the time came for transplanting the rice, the *genge* was still very small, and had not yet accumulated much nitrogen.

These researches were made on 12 plots which were supplied, before sowing the *genge*, with a large quantily of phosphoric acid and potash; 9 out of the 12 plots received also lime in various quantities (20, 30, and 40 kilogrms. per *tan*). In spite of the imperfect development of *genge* the green manure produced a distinct and not inconsiderable effect on the yield of rice on all those plots which received lime.[9]

Before the rice was cut in 1889, *genge* was again sown on the same 12 plots, and showed a fair development in the autumn. During the winter it was covered with a little straw to prevent the young plants from being thrown up by frost. On the 9th and 10th of May 1890, when these were in full blossom, they were cut, weighed, and mixed with the soil. The amount of green manure thus obtained was as follows, average of three plots:

Lime applied to the preceding crop, kilogrms. per *tan*	0	10	20	40
Green *genge*, grms, per plot ...	840	1548	1527	1257
,, ,, kilogrms. per *tan* ...	1008	1858	1832	1508

Genge requires accordingly some lime in the manure, but, even on our soil so rich in humus and inclined to sourness, 10 kilogrms. per *tan* were quite sufficient.

According to an analysis made in 1891, we found in flowering *genge* plants 12.23 % of dry matter and 0.369 % of nitrogen. Hence the approximate content of the crop harvested on the 9 plots supplied with lime, was per plot 212 grms. of dry matter and 6.40 grms. of nitrogen, i. e. per *tan* 254 kilogrms. of dry matter and 7.7 kilogrms. of nitrogen. These figures do not, however, represent the content of the whole plants, as they do not comprise the stubbles and roots left in the soil.

Before transplanting the rice, phosphoric acid (11 kilogrms.) and potash (11 kilogrms.) were again applied, the former as sodium phosphate, the latter as carbonate. In order to study the influence of lime on the action of the green manure, the

9 See bulletin No. 8, p. 7, 8, and 12.

respective plots again received the same quantities of slaked lime as in the preceding season. The rice developed with great regularity, no injuries being noticed in spite of the large amount of organic substance incorporated with the soil in the green manure.

The yield in the 4 different trials is shown by the following table, to which we may add the produce obtained from the plots with complete manure and those which had not received any nitrogenous manure (p. 4).

	Per plot, grms.				Per *tan*.		
	Straw.	Full grain.	Empty grain.	Whole crop.	Straw. kilograms.	Chaff kilograms.	Hulled grain, *koku*.
Without nitrogen	536	412.7	3.2	952	643	99	2.81
Genge without lime	623	464.2	4.2	1091	747	114	3.20
,, + 10 kilogrms. lime.	837	633.7	5.3	1474	1004	155	4.38
,, + 20 ,, ,,	825	616.3	5.5	1447	990	150	4.25
,, + 40 ,, ,,	860	646.2	4.6	1511	1032	156	4.44
Complete manure	975	638.1	7.6	1621	1170	157	4.34

It will be seen that by the cultivation of *genge* with the application of lime, the produce, especially as regards grain, was not inferior in quantity to the yield from the plots with complete manure in which a large quantity of nitrogen (11 kilogrms. per *tan*) had been applied in the form of ammonium sulphate. Where, however, no lime had been given, the increase of the crop over the plot without nitrogen was comparatively small, owing to the inferior development of the *genge*, and probably also to the insufficient decomposition of the green manure in the soil.

The quantities of nitrogen consumed by the rice from the soil and manure on the various plots were determined by analysis which gave the following results:

	Nitrogen in the whole crop. per plot, grms.	per *tan*, kilogrms.
Without nitrogen	7.43	8.92
Genge without lime	8.18	9.82
,, + 10 kliogrms. lime	11.84	14.21
,, + 20 ,, ,, ...	11.52	13.82
,, + 40 ,, ,, ...	12.18	14.61
Complete manure	12.46	14.95

In the average of the 9 plots which had been cultivated with *genge* and manured with 10—40 kilogrms, of lime the total nitrogen assimilated by rice per *tan* was accordingly 14.21 kilogrms. while from the three plots without nitrogenous manure only 8.92 kilogrms. was taken up. Hence, 5.29 kilogrms. had been rendered available for rice by *genge* and lime. Assuming the available nitrogen to have been converted before its consumption into ammonical compounds from which, according to our previous researches 62.2 % can be taken up by rice, we find that about 8.5 kilogrms. of nitrogen was rendered available by the fixation of free nitrogen from the air in the leguminous manure and by the action of lime on the latter as well as on the nitrogenous constituents in the soil. This quantity is, indeed, very large, and, as demonstrated by our experiments, suffices for maximum yield of rice. Truly, the cultivation of *genge* if rationally carried out, is very remunerative, and deserves to be far more extended in the rice growing districts than it is at present.

Whenever it is intended to raise *genge* for green manuring it must not be forgotten that this crop also requires some manure, especially phosphoric acid and lime. Hence the rice preceding the *genge* should receive, in addition to the ordinary manure per *tan* about 4—6 kilogrms. of available phosphoric acid in the form of superphosphate, precipitated calcic phosphate or Thomas phosphate, and 20—50 kilogrms. of lime, unless the land has been previously dressed with this manure. Instead of lime also wood ashes will serve the

purpose very well, especially as they increase the stock of potash in the soil. The lime or ashes may be put into the soil a fortnight, superphosphate and precipitated phosphate 3—4 days, before transplanting, the Thomas phosphate as early as possible, and as this fertilizer is rich in calcium compounds, the dose of lime may be somewhat reduced. Several days after the final irrigation, *genge* is sown broad-cast and rather thickly, and during the winter the field must be kept dry and the plants covered with a little straw. In the following spring when the *genge* is in full blossom it is cut, well mixed with the soil, which should not be irrigatad too early lest the decomposition of the green manure be retarded. Before transplanting the rice, again some phosphatic manure, about 4 kilogrms. of available phosphoric acid per *tan* should be applied. If the *genge* has grown normally, no other manure will be required.

IV. Series.

COMPARATIVE EXPERIMENTS ON THE EFFECT OF VARIOUS PHOSPHATES ON RICE.

These experiments were carried out on 57 plots newly arranged in a section of the paddy field of the college farm. The condition of the soil and the water used for irrigation were the same as in the researches of 1889. The following phosphatic fertilizers were applied :

1) *Sodium phosphate* containing 19.79 % phosphoric acid.
2) *Double superphosphate* with 47.84 % total phosphoric acid, of which 43.65% was soluble in water, 3.08% soluble in neutral ammonium citrate solution, and 1.1% soluble in mineral acids.
3) *Precipitated calcium phosphate* with 29.35% total phos-

phoric acid, of which 24.80% was soluble in neutral citrate solution and 4.55% soluble in mineral acids.

4) *Peruvian guano*, undissolved, containing 14.18% phosphoric acid and 7.61% nitrogen.
5) *Thomas phosphate* with 21.75% phosphoric acid and 75% fine powder of a diameter of 0.1 millimetres.
6) *Steamed bone dust* containing 23.06% phosphoric acid, 3.87% nitrogen, and 1.33% fat. The separation with chloroform showed that in 100 parts of the manure 0.94% of the nitrogen was not in the form of bony substance; hence the proportion of nitrogen to phosphoric acid in the bony part was 1 : 7.9, showing that a considerable part of the gelatogenous substance had been extracted.
7) *Crude bone dust* containing 19.70% phosphoric acid, 4.74% nitrogen and 1.93% fat. From 100 parts of the manure 0.71% of nitrogen could be separated by chloroform as not belonging to the bony part; hence the proportion of nitrogen to the phosphoric acid in the bony part was 1 : 4.9, which enables us to conclude that no gelatogenous substance had been extracted from the bones.
8) *Bone ash* containing 30.465% total phosphoric acid; 4.89% phosphoric acid were dissolved by neutral citrate solution.
9) *Podolian phosphorite* containing 35.02% total phosphoric acid; 1.24% were dissolved by citrate solution.

The mechanical condition of the manures No. 6—9 as determined with a set of sieves with round holes, was as follows:

Diameter of the particles.	Steamed bone dust.	Crude bone dust.	Bone ash.	Phosphorite.
Less than 0.25 millimetre...	...84.9	37.8	54.8	93.0
0.25—0.5 ,, ...	...11.1	25.2	21.7	6.9
0.5—1 ,, ...	... 4.0	35.9	10.6	0.1
1—2 ,, ...	... —	1.1	12.9	—

The other manures used were ammonium solphate and potassium carbonate, of which equal quantities containing per

tan 11 kilogramms of nitrogen and 11 kilogramms of potash, were applied to all plots alike.

The general plan of the experiments will be seen from the following compilation in which the figures given for the phosphoric acid, signify total phosphoric acid without reference to its solubility.

No. of plots.			Kind of phosphate.	Phosphoric acid applied	
				per plot grms.	per *tan* kilogrms.
1,	20,	39.	Without phosphoric acid.	0	0
2,	21,	40.	Sodium phosphate.. ..	3.67	4.40
3,	22,	41.	,, ,, ...	7.34	8.80
4,	23,	42.	Double superphosphate.	3.89	4.67
5,	24,	43.	,, ,,	7.78	9.34
6,	25,	44.	Precipitated phosphate..	4.59	5.50
7,	26,	45.	,, ,, ..	9.18	11.00
8,	27,	46.	Peruvian guano	6.97	8.36
9,	28,	47.	,, ,, ...	13.94	16.72
10,	29,	48.	Thomas phosphate ..	6.885	8.26
11,	30,	49.	,, ,, ..	13.77	16.52
12,	31,	50.	Steamed bone dust ..	6.885	8.26
13,	32,	51.	,, ,, ,, ..	13.77	16.52
14,	33,	52.	Crude bone dust	6.885	8.26
15,	34,	53.	,, ,, ,, ...	13.77	16.52
16,	35,	54.	Bone ash..	6.885	8.26
17,	36,	55.	,, ,, ...	13.77	16.52
18,	37,	56.	Phosphorite	6.885	8.26
19,	38,	57.	,, ...	13.77	16.52

With each kind of manure 6 single trials were accordingly made, 3 with a small quantity and 3 with a large one, the latter being just the double of the former.

The yield, average of 3 equally treated plots was, as follows :

Kind of phosphate	Phosphoric acid per *tan* kilo-grms.	Produce per plot				Hulled grain per *tan*		
		Straw grms.	Full grain grms.	Empty grain grms.	Whole crop grms.	kilo-grms.	*koku.*	surplus over the plot without phosphoric acid kilo-grms.
Without phosphoric acid..	0	373	263.4	3.3	639	255	1.79	—
Sodium phosphate	4.40	481	378.5	5.5	863	367	2.58	112
	8.80	645	531.0	5.7	1182	514	3.61	259
Double superphosphate	4.67	651	507.8	7.9	1167	492	3.46	237
	9.34	766	615.5	9.2	1391	596	4.19	341
Precipitated calcium phosphate	5.50	711	570.8	4.7	1287	553	3.89	298
	11.00	901	679.2	12.8	1593	658	4.62	403
Peruvian guano ..	8.36	567	409.2	4.3	981	396	2.78	141
	16.72	621	458.2	5.5	1085	444	3.12	189
Thomas phosphate	8.26	623	476.2	5.8	1105	461	3.24	206
	16.52	785	585.6	10.4	1381	567	3.98	312
Steamed bone dust	8.26	652	492.5	8.8	1154	477	3.35	222
	16.52	821	644.1	12.6	1478	624	4.38	369
Crude bone dust	8.26	663	522.4	10.3	1196	506	3.56	251
	16.52	925	717.8	16.9	1660	695	4.88	440
Bone ash	8.26	502	388.8	4.9	896	377	2.65	122
	16.52	654	522.7	5.6	1183	506	3.56	251
Phosphorite.. ..	8.26	409	319.7	3.2	731	310	2.18	55
	16.52	381	313.6	2.9	698	304	2.14	49

It is thus seen that in all the trials the phosphatic manure increased the yield of straw and grain, and that the yield produced by the larger amount of phosphoric acid was considerably higher than that obtained with the smaller quantity.

This proves that the smaller doses of phosphoric acid displayed throughout all trials their full action and that the increase obtained with them over the plot without phosphoric acid, gives a reliable measure of the relative value of the various phosphates applied. As in paddy fields rice is mostly the only crop cultivated and as the farmer determines the value of the

harvest on the basis of the produce of *hulled grain*, we may now calculate, firstly, the increase of this product over the plot without phosphatic manure caused by 10 kilogrms of phosphoric acid in the case of the smaller doses of this nutrient, and secondly, the relations of these surplus yields to that effected by the phosphoric acid of superphosphate :

	Increase of hulled grain for 10 kilogrms. of phosphoric acid. kilogrms.	Relations of the increase, phosphoric acid of superphosphate = 100
Superphosphate	508	100
Sodium phosphate	255	50.2
Precipitated calcium phosphate	544	107.1
Peruvian guano	169	33.3
Thomas phosphate	248	48.8
Steamed bone dust	269	53.0
Crude bone dust	304	59.8
Bone ash	148	29.1
Phosphorite	60	11.8

Before entering into a discussion of these results we may consider the proportions of phosphoric acid consumed by the plants from the soil and manure, as found by the chemical analysis.

	Phosphoric acid in the manure. grms.	Phophosric acid in the whole crop. grms.	Phosphoric acid consumed from the manure.	
			grms.	per cent of the phosphoric acid applied.
Without phosphoric acid	0	0.915	—	—
Sodium phosphate	3.67	1.316	0.401	10.9
,, ,, ...	7.34	1.936	1.021	13.9
Double superphosphate	3.89	1.854	0.939	24.1
,, ,, ...	7.78	2.290	1.375	17.7
Precipitated phosphate	4.59	2.067	1.152	25.1
,, ,, ...	9.18	2.565	1.650	18.0
Peruvian guano	6.97	1.496	0.581	8.3
,, ,, ...	13.94	1.787	0.872	6.3
Thomas phosphate	6.885	1.859	0.944	13.7
,, ,, ...	13.77	2.332	1.417	10.3
Steamed bone dust	6.885	1.889	0.974	14.15
,, ,, ,, ...	13.77	3.024	2.109	15.3
Crude bone dust	6.885	1.918	1.003	14.6
,, ,, ,, ...	13.77	3.339	2.124	15.4
Bone ash	6.885	1.371	0.456	6.6
,, ,, ...	13.77	1.939	1.024	7.4
Phosphorite	6.885	1.033	0.118	1.7
,, ...	13.77	0.997	0.082	0.6

The figures given for the absolute quantities consumed per plot indicate that, with the exception of the phosphorite, from the larger doses of phosphatic manure considerably more was taken up than from the smaller ones, so that here also the results obtained with the smaller doses are sure to yield reliable information on the assimilability of various forms of phosphoric acid. Assuming the assimilability of the phosphoric acid of the superphosphate (24.1%) to be 100, and calculating, on this basis, the relative assimilability of the other forms of phosphoric acid we obtain the following results to which we add

for comparison the relative effect on the increase of hulled grain.*

	Relative assimilability.	Relative action on the increase of hulled grain.	Relative manurial value in the first season.
Double superphosphate	100	100	**100**
Precipitated phosphate	104.0	107.1	**106**
Crude bone dust	60.4	59.8	**60**
Steamed bone dust	58.6	53.0	**56**
Thomas phosphate	56.9	48.8	**53**
Sodium phosphate	45.3	50.2	**48**
Peruvian guano	34.4	33.3	**34**
Bone ash	27.4	29.1	**28**
Phosphorite	7.1	11.8	**9**

There is a most satisfactory coincidence in the relative assimilability of the various phosphates and their relative action on the increase of hulled grain. The average of the two series of results given above in the 3rd column, constitutes accordingly the standard for the calculation of the quantities of the various phosphates suited for rice under conditions similar to ours in respect to soil and climate.

Before we consider the relative effect of the various phosphates on crops we may quote here the results obtained by P. Wagner[10] on dry land in cylindrical pots of a diameter of and height of 20 centimetres. With moderate doses similar to ours he obtained in the average of three closely coinciding series of parallel experiments with wheat, barley, and flax, the following results as to the relative effects, that of the soluble phosphoric acid in superphosphates being reckoned as 100:

* The figures of the following table differ slightly from those given by me in a lecture before the Agricultural Society of Japan, because in the latter case the small amount of dust adhering to the full grain had not been taken into account.

10 Wagner, Thomas phosphate powder, 1887, p. 23.

	Wagner.	Our results with rice.
Superphosphate	100	100
Thomas phosphate	50	53
Peruvian guano	30	34
Steamed bone dust	10	56
Coprolite powder	9	9[11]

In spite of the great differences in the conditions of soil and climate as well as the character of the crops in Wagner's experiments and in our own, we find a striking resemblance between his results and ours. Indeed, as to the relative value of *superphosphate*, *Thomas phosphate*, *Peruvian guano*, and *phosphorite* there is such a close coincidence between the two series of experiments as would be satisfactory even if obtained from parallel trials made under exactly the same conditions. With reference to the *steamed bone dust*, however, a great difference will be noticed between our figures and Wagner's; while we found, on the irrigated land, the action of the phosphoric acid of this fertilizer to amount to as much as 56% of that of the phosphoric acid of superphosphate, Wagner observed it to be only 9%. In both cases the results are not the outcome of a single observation, but Wagner's experiments were made on two kinds of soil with 5 crops[12] and ours are likewise confirmed by the trials with crude bone dust, altogether on 12 single plots, as well as by new researches on dry land with barley[12]. The effect of bone dust varies accordingly within wide limits, the dependency of which on the conditions of soil, moisture, and climate needs still further investigation.

Hitherto we have taken into consideration only the increase of the crop and the assimilability of phosphoric acid on the plots supplied with the smaller doses of phosphates. The larger doses no longer exerted their full action on the yield,

---

11 Powdered phosphorite.

12 A report on these experiments will be published in one of the next bulletins.

but as to the assimilability some of them gave results very similar to those obtained with the lesser quantities of manures. Thus we found the following relations of the assimilability, that of the phosphoric acid of superphosphate being reckoned as 100:

	Superphosphate.	Precipitated phosphate.	Thomas phosphate.	Peruvian guano.
Small dose	100	104	56.9	34.4
Large dose	100	102	57.1	35.6

With reference to the other manures, except phosphorite and sodium phosphate, the proportions taken up from 100 parts of the phosphoric acid applied, were nearly the same with the small as with the large doses. The results were thus:

	Steamed bone dust.	Crude bone dust.	Bone ash.
Small dose	14.15 %	14.6 %	6.6 %
Large dose	15.32 ,,	15.4 ,,	7.4 ,,

A somewhat peculiar deportment is displayed by the sodium phosphate, with which we obtained the following figures, the effect of the phosphoric acid of the superphosphate being reckoned as 100:

	Relative increase of hulled grain.	Relative consumption by the crop.
Small dose	50.2	45.3
Large dose	86.2	78.8

What surprises us here first, is the low rate of consumption and the small increase of the crop in comparison with the superphosphate. We are inclined to expect the sodium phosphate, on account of its greater solubility, to undergo a still better distribution in the soil and thus to be more accessible to the roots and more effective on the crop than even the superphosphate, but the experiment contradicts that anticipation. In the second place it strikes us that, contrary to the deportment of the other manures, the small dose of sodium phosphate was consumed to a relatively less extent, and produced a relatively less increase of the crop than the large dose. The only explanation that can be given for these results, is

the peculiar deportment of the sodium phosphate towards our soil. Owing to the richness of the latter in hydrated sesquioxides of iron and alumina the phosphoric acid of this salt is speedily precipitated, especially if it is applied as it was in these experiments, in the dissolved state; and in the precipitate the sesquioxides will, of course, predominate the more, the less phosphoric acid is incorparated with the soil. Thus, with large doses of sodium phosphate, the products of the absorption in the soil are of a less basic character and can accordingly be more easily and completely taken up by the roots than if small doses were applied. The active ingredient of superphosphates, i. e. monocalcium phosphate, on the other side, is not so soluble in water; therefore the solid particles when put into the soil come into contact with a less quantity of sesquioxides and yield besides dicalcic phosphate compounds of a less basic condition than the sodium phosphate. Hence the phosphoric acid of the superphosphate must have in soils like ours a better effect than sodium phosphate. For the same reason the granulation of superphosphates is, to some extent, connected with the effect. In a very finely pulverized state and if well mixed with a soil rich in sesquioxides, they may favour too much the formation of basic phosphates and thus become less effective than the more coarsely granulated kinds. Researches by P. Wagner[13] on a sandy soil very poor in lime with finely powdered and coarse particles of superphosphate (the latter having a diameter of 1.5-2 millimetres), proved, indeed, the action of the former to be about 60% lower than that of the latter, but this author holds the excessive distribution alone to be responsible for the inferior action of the fertilizer, where as our experiments give evidence that the chemical condition of the products of the absorption in the soil may also vary according to the size of the particles, and may likewise account for his result.

In our researches the best effect on rice was exerted by the

---

13 Important practical questions on the subject of manures, 1885, p. 48.

precipitated calcium phosphate, which consisted chiefly of dicalcium phosphate; and very nearly the same action was displayed by the superphosphate the greater part of which was made up of monocalcium phosphate. A slight superiority of the former over the latter has already been noticed by numerous authors among whom we may mention A. Petermann,[14] L. Grandeau,[15] J. Fittbogen,[16] E. Wein,[17] and M. Mærker[18]. In general it appears from these experiments that on those soils which exhibit an extreme deportment towards soluble phosphates i.e. which have either a very low, or a very high absorptive power for their nutrient, the dicalcium phosphate or reverted phosphates act better than the monocalcium phosphate of superphosphates. Where the absorptive power is very low, the soluble phosphoric acid may diffuse through so large a volume of soil that the roots cannot extract enough of it; and, on the other side, if the soil is very rich in absorbent constituents a considerable formation of basic phosphates may take place, which yield their phosphoric acid to the roots with difficulty. The superphosphates are therefore suited principally for soils of a medium condition, while the dicalcium phosphate (precipitate) can be used for all kinds of soils. The manufacture of precipitated phosphates has lately been so improved that a content of 35 and even 42% of phosphoric acid almost completely soluble in ammonium citrate is guaranteed by the factories; and as in spite of their richness and great efficacy these phosphates sometimes command lower prices than superphosphates, they deserve to be recommended for importation. Although only faintly soluble in water, their distribution in paddy fields will not be difficult in Japan where the preparation of the fields is so careful and the soil is worked on to a sufficient depth. The quantity of phosphoric acid to

---

14 Landw. Versuchsstationen, vol. 24, p. 321.

15 Biedermann's Centralblatt für Agriculturchemie, vol. 7, p. 650.

16 Ibid. vol. 14, 18 p. 313. vol. 7, p. 650.

17 Ibid. vol. 9, 18 p. 647.

18 Ibid. vol. 10, 18 p. 378.

be applied per *tan* in addition to the common manures may between 1-1.5 *kwamme*[19] the smaller dose being sufficient for fields formerly frequently manured with rice bran, fish manure or oil cakes, the larger in those cases where green manure, farmyard manure, night-soil, etc., are principally used.

Next, as to manurial value, come the two kinds of *bone dust*. Of these the steamed sort had a slightly lower effect than the crude kind, probably because the former had lost some of the gelatogenous substance during manufacture which is supposed to play an essential part in the dissolution of the bone phosphate in the soil. In general, their effect was, as already mentioned, very high, surpassing that of the phosphoric acid of Thomas phosphate and Peruvian guano; but whether this will also be so on soils in a different condition, especially on irrigated heavy land, is doubtful, and requires further investigation. In cases similar to ours 10 *kwamme* of finely powdered bone dust to the *tan* will suffice. It is advisable to incorparate this manure rather early with the soil or to ferment it slightly before its application, especially if it consists of coarse grains, and is not free from fat. As the bone manure contains besides phosphoric acid about 3-5% nitrogen, the quantity of the other fertilizers to be applied may be correspondingly diminished.

The *Thomas phosphate* proved to be only slightly inferior to the bone dust and is suited to all kinds of irrigated soils. Per *tan* about 2-3 *kwamme* of phosphoric acid in this form of manure will secure a good crop.

Peruvian guano and *bone ash* had both a rather low effect, and are not to be recommended either for rice or for dry land crops. After treatment with sulphuric acid, i.e. in the form of superphosphate, they will, of course, exert a good effect, and should always be converted into this kind of fertilizer. Peruvian guano is, however, at present too expensive to be imported.

The least effect was obtained by the application of *phosphorite*

19 1 *kwamme* = 3.7565 kilogrms.

powder, in spite of its very fine division. Good results may be expected with this phosphate only on peat or moor land rich in sour humus which has the capacity for dissolving considerable quantities of phosphoric acid from this mineral fertilizer. As soils of this kind are, however, rare in Japan, it will be advisable to discontinue the separation of so-called "floats" i.e. the finest dust obtained while grinding the raw phosphorite in superphosphate factories and to convert these "floats," along with the other particles, into superphosphate.

Our experiments will be continued in the coming season in order to determine the effect of the unrecovered phosphoric acid.

V. Series.

COMPARATIVE EXPERIMENTS ON THE EFFECT OF VARIOUS NITROGENOUS MANURES ON RICE.

This series occupied a section of the paddy field of the college farm adjoining that on which the phosphatic manures were tested, and comprised 105 plots, of which 6 were not supplied with nitrogen, while the other 99 received various nitrogenous fertilizers, each of which was applied in two doses containing *a* 3.45 grms. per plot=4.14 kilogrms. per *tan* and *b* 7.90 grms. per plot=8.28 kilogrms. per *tan;* the doses *b* being, therefore the double of *a*. To all plots alike a general manure was applied consisting per *tan* of 22 kilogrms. of phosphoric acid as sodium phosphate and 11 kilogrms. of potash as carbonate.

The following nitrogenous fertilizers were tested in this way:

1) *Ammonium sulphate*, which was applied in the form of a solution. About 3 kilogrms. of the wet soil of the

respective plots were mixed in a spacious beaker with the solution, and after two days' standing were incorporated with the plot.

2) *Night-soil*, well decomposed, containing 0.505% nitrogen.
3) Fish-manure, *shime-kasu*, with 9.54% nitrogen and 14.19% fat.
4) Fish-manure, *hoshika*, with 9.92% nitrogen and 3.63% fat, consisting of very small fish called *gomame*.
5) *Blood meal*, with 13.82% nitrogen.
6) *Flesh meal*, containing 4.77% nitrogen.
7) *Steamed bone dust*, the same kind as used in series IV; it contained 3.87% nitrogen of which only 2.93% existed in the bony substance. The proportion of nitrogen to phosphoric acid in the bony part 1 : 7.9, indicates that a considerable part of the gelatogenous substance had been extracted.
8) *Crude bone dust*, the same kind as used in series IV; containing 4.74% nitrogen, of which 4.03% existed in the bony tissue. The proportion of nitrogen to phosphoric acid in the bony part 1 : 4.9 indicates that no gelatogenous substance had been extracted. The fertilizer contained only a small quantity of fat, and was in a well powdered condition.
9) *Peruvian guano*, undissolved, but well powdered, containing 7.61% nitrogen. This fertilizer was tested only on 3 plots, to which a dose of nitrogen amounting to 4.95 grms. per plot = 5.95 kilogrms. per *tan* was applied.
10) *Farmyard manure* prepared from a mixture of stable manure and night-soil, and well fermented. It contained 1.069% nitrogen, half of which may be assumed to exist in the form of night-soil.
11) *Green plants*, chiefly gramineæ cut immediately before transplanting the rice. They contained 0.474% nitrogen, and were applied without previous fermentation.
12) *Rice bran* containing 2.07% nitrogen; these also were not fermented before application.

13) *Rape cake* containing 5.03% nitrogen and 9.30% fat.
14) *Shōyu cake* containing 3.495% nitrogen.
15) *Shōchū cake* with 2.30% nitrogen.
16) *Horn meal* with 14.69% nitrogen.
17) *Straw* of wheat containing 0.9665% nitrogen and applied without previous fermentation.

All these manures were incorporated with the soil several days before transplanting the rice, due care being taken to allow the soluble nutrients to undergo complete absorption before commencing the irrigation.

The growth of the plants did not exhibit any irregularity, except on the plots supplied with green manure, rice bran, straw, and to a slight extent also, on those with blood meal. There, these manures appear to have undergone a rapid fermentation partly connected with a formation of organic acids, and associated throughout with reducing processes; ferrous compounds, which dissolved in the water and formed, on gradual oxidation, thin coloured membranes on the surface. As the available oxygen in the soil was thus consumed by the decaying substances, the roots were insufficiently supplied with this gas, and the plants turned pale, showing but a slow development for about a month. Later on, after the fermentation was completed, the plants assumed a normal appearance but remained, as to the size and production of accessory stems, inferior to the other plots.

These observations evidently show that manures rich in easily decomposable organic matter, should be well fermented before they are applied to irrigated land. Green manure, rice bran, straw, leaves, etc., should therefore invariably be well decomposed in the compost bed, or applied 3-4 weeks before transplantation.

The yields of straw, grain, and empty hulls, as well as the increase produced by the nitrogenous fertilizers over the plots which were not supplied with nitrogenous food, are recorded in the following table:

Kind of manure.	Number of plots.	Dose of nitrogen per plot.[20]	Yield, average per plot, grms.				
			Straw.	Full grain.	Empty grain.	Whole crop.	Hulled grain.
Without nitrogen	1-36-71	—	618	451.1	3.2	1072	364.1
	19-54-89	—					
Ammonium sulphate	2-37-72	a	709	550.6	5.1	1265	444.4
	3-38-73	b	881	592.3	9.2	1483	478.1
Night-soil	4-39-74	a	817	553.9	5.6	1377	447.1
	5-40-75	b	908	593.0	7.9	1509	478.7
Shime-kasu	6-41-76	a	777	585.0	6.0	1368	472.2
	7-42-77	b	863	672.4	9.9	1545	542.7
Hoshika	8-43-78	a	767	585.8	5.5	1358	472.9
	9-44-79	b	816	639.4	7.2	1463	516.1
Blood meal	10-45-80	a	733	576.1	6.9	1316	465.9
	11-46-81	b	824	608.3	7.6	1440	491.0
Flesh meal	12-47-82	a	678	477.1	4.0	1159	385.1
	13-48-83	b	768	573.0	7.0	1348	462.5
Steamed bone dust	14-49-84	a	851	593.6	7.1	1452	479.2
	15-50-85	b	1006	687.4	5.3	1699	554.9
Crude bone dust	16-51-86	a	791	570.8	6.5	1368	460.7
	17-52-87	b	998	679.4	6.9	1684	548.4
Peruvian guano	18-53-88	c	899	613.6	11.5	1524	495.3
Farmyard manure	20-55-90	a	742	545.7	4.6	1292	440.5
	21-56-91	b	789	580.8	5.8	1376	468.8
Green plants	22-57-92	a	665	496.8	4.2	1166	401.0
	23-58-93	b	678	552.2	5.8	1236	445.7
Rice bran	24-59-94	a	641	505.1	4.0	1150	407.7
	25-60-95	b	703	549.1	6.9	1259	443.4
Rape cake	26-61-96	a	776	551.8	7.5	1335	445.4
	27-62-97	b	904	627.1	4.7	1536	501.8
Shōyu cake	28-63-98	a	742	552.9	6.1	1301	446.3
	29-64-99	b	825	601.1	6.9	1433	485.2
Shōchū cake	30-65-100	a	850	570.0	5.3	1425	460.1
	31-66-101	b	960	663.0	7.7	1631	535.2
Horn meal	32-67-102	a	726	567.3	6.9	1300	457.9
	33-68-103	b	743	600.4	5.6	1349	484.6
Straw	34-69-104	a	496	420.1	3.1	919	339.1
	35-70-105	b	509	410.5	4.8	925	331.4

20 Doses per plot: *a*) = 3.45; *b*) = 6.90; *c*) = 4.95 grms. nitrogen.

In all cases in which the double doses (*b*) of nitrogen were applied, the produce of grain and particularly of straw showed a remarkable increase over the plots with the single doses (*a*) but there is no exact proportionality of the increases caused by the two doses over those plots which were not supplied with nitrogenous manure. While the small quantities of the fertilizers were enabled to exert their maximum effect on the produce, the large doses were not so well utilized, and they displayed accordingly only a fraction of their effect. As the value of fertilizers for paddy fields will always be determined by their action on the produce of hulled grain, we give in the following table[21] the increases of this product caused by the small doses of nitrogen over the plots not manured with this nutrient, and in order to compare the values of the various fertilizers we add in the last column the "relative increases," the effect of the night-soil being reckoned as 100.

21 In this compilation the increase caused by the Peruvian guano (4.95 grms. nitrogen) is reduced to the increase corresponding to the amount of nitrogen (3.95 grms) applied in the other kinds of manures. The flesh meal which had been charred during its preparation and was accordingly unable to display a normal action, is excluded from further discussions.

	Increase of hulled grain over the plots not supplied with nitrogen,			Relative increase, night-soil = 100.
	per plot grms.	caused by 10 kilogrms. of nitrogen in the manure.		
		kilogrms.	koku.	
1) Night-soil	83.0	241	1.69	100
2) Steamed bone dust	115.1	334	2.35	140
3) Hoshika	108.9	316	2.21	131
4) Shime kasu	108.1	313	2.19	130
5) Blood meal	100.1	290	2.03	125
6) Crude bone dust	96.6	280	1.97	116
7) Shōchū cake	96.1	279	1.96	115
8) Horn meal..	93.8	272	1.91	112
9) Peruvian guano	91.5	265	1.86	110
10) Shōyu cake	82.2	238	1.67	99
11) Rape cake	81.3	236	1.66	98
12) Ammonium sulphate ..	80.3	233	1.64	97
13) Farmyard manure	76.4	222	1.56	92
14) Rice bran	43.6	126	0.89	53
15) Green plants	36.9	107	0.75	44

These figures tend to prove the interesting fact that the majority of the organic nitrogenous fertilizers, such as bone dust, fish manure, powdered horn, blood meal, and shōchū cake surpass in their action the ammoniacal compounds in the form of night-soil and ammonium sulphate. The presence of much water, and its high temperature during the irrigation appears to have a powerful influence on the decay of organic substances and the formation of ammonia in paddy fields. Former observations[22] made in conjunction with Mr. J. Sawano have shown that the temperature of the water on irrigated land sometimes surpasses even the maximum temperature of the air; we found in researches comprising three periods, each of 12 consecutive days, the following figures:

22 Landwirthschaftliche Versuchsstationen. Vol. 33, 1883, p. 37.

	Temperature of the water observed at 8.30 a. m.		Temperature of the air in the corresponding 24 hours.	
	incoming water.	effluent water.	minimum.	maximum.
From the 22nd of June to the 3rd of July	...23.1 °C.	28.3 °C.1	6.7 °C.	26.7 °C.
From the 13th to the 24th of July ...	...23.9 ,,	28.6 ,,	20.4 ,,	29.8 ,,
From the 8th to the 23rd of August	...22.0 ,,	23.3 ,,	19.5 ,,	30.0 ,,

It is evident that in water of so high a temperature the decomposition of organic substances must be very vigorous. Yet the process is accomplished slowly enough to ensure a pretty complete absorption of the ammonia thus originated, by the soil and a constant supply of assimilable food to the plants. On those plots where ammoniacal compounds were applied as such, some of the ammonia seems to have been washed away by the irrigation or to have escaped into the air, in spite of the very high absorptive power our soil has for ammonia; otherwise the effect of these fertilizers (night-soil and ammonium sulphate) would not have been inferior to that of organic fertilizers. Some of the nitrogenous organic manures, viz. shōyu cake and rape cake, did not act so well as the manures of purely animal origin but still they were practically equal to the ammoniacal fertilizers. As their decomposition in the soil seems to be less rapid, a slight fermentation in the compost bed may be recommended before their application. As to the farmyard manure we may remember that it consisted of a well fermented mixture of stable manure and night-soil. Assuming half the amount of nitrogen to have been present in the form of night-soil, the relative action of the farmyard manure alone, as compared with that of night-soil (= 100), would amount to only 84. In common practice, the farmyard manure will certainly have a far lower action, possibly 50 or less, because its collection leaves, at present, much to be desired

especially as regards the urine which is mostly lost from the stable. Rice brans, green manure, and straw when freshly applied, as in our experiments, injure the plants through formation of acid and reducing processes. They should accordingly be invariably fermented before their application or put into, and mixed with, the soil several weeks before transplantation. If thus treated rice bran will probably be not much less effective than the rape cake was in our experiments. In general, for rice fields the preparation of good compost deserves to be much recommended.

Referring then to the consumption of nitrogen by the crops, we find that plants grown on the plots without nitrogenous manure contained 7.98 grms. of nitrogen per plot, and as 1.77 grms. were contained in the plants from the seed bed, the amount of soil nitrogen consumed per frame was 6.21 grms. = 7.45 kilogramms per *tan*. In the crops supplied with 3.45 grms. of nitrogen in the form of various fertilizers we found the following amounts, from which we calculate how much was consumed from 100 parts of the nitrogen applied.

	Nitrogen in the whole crop. grms.	Consumed from the manure. grms.	Consumed per cent of the nitrogen applied.
Steamed bone dust	10.96	2.98	80
Hoshika	10.35	2.37	
Shimekasu	10.77	2.79	
Blood meal	10.82	2.84	
Crude bone dust	10.51	2.53	72
Shōchū cake	10.45	2.47	
Horn meal	10.42	2.54	
Peruvian guano	10.45	2.47	
Shōyu cake	10.23	2.25	67
Rape cake	10.32	2.34	
Night-soil	10.26	2.28	66
Ammonium sulphate	10.10	2.12	61
Farmyard manure	9.70	1.72	50
Rice bran	8.88	0.90	26
Green plants	8.76	0.78	23

The proportion of nitrogen consumed from the manure is, according to these figures very considerable, largely excceeding the quantities taken up from the manures applied on dry land. On the latter, researches reported in bulletin No. 6 (p.31), have shown that from 100 parts of nitrogen applied there was consumed by barley:

from night-soil	41 %
,, ammonium sulphate	40 ,,
,, fish manure	47 ,,
,, steamed bone dust	55 ,,

Barley, it is true, has shorter roots than rice, and feeds chiefly on the surface soil, but other deep-rooted cereals, like wheat, are also incapable of consuming such high rates of nitrogen as rice does in irrigated land. The rapid process of nitrification in dry soils converts the decomposable nitrogenous compounds too speedily into nitrates which cannot be retained by the soil but are washed down beyond the range of the roots, and thus escape consumption by the plants; whereas in paddy soils, while they are being irrigated, nitrates are not formed, but ammonia is the final product of decay which is strongly retained in most soils, thus admitting of a more complete utilization by the plants. *The economy of manures is accordingly greater in paddy fields than on dry land.*

As to the rate of the consumption of nitrogen from the various fertilizers, we notice in our experiments marked differences. In harmony with the effect on the yield the largest proportions of nitrogen (80%) are consumed from the easily decomposable manures of purely animal origin (steamed bone dust, fish manure, dried powdered blood); next come crude bone dust, shōchū cake, horn meal, and Peruvian guano, with an "asssimilation-factor," as we may call it, of 72%; a little less decomposable are the rape cake and the shōyu cake, for which a preparatory treatment in the compost bed is advisable also in view of this result; night-soil yields a little more nitrogen (66%) to the rice than ammonium sulphate, for which in this season very nearly the same assimilation-factor (61.4) was found as in

the last year (62.2); for the farmyard manure alone, eliminating by calculation its content of night-soil, we find that 34% of its nitrogen will probably have entered the crop, which proportion will diminish in practical farming possibly to 20% because of the incomplete collection of the urine, and the insufficient fermentation; the least quantity of nitrogen was consumed from the rice bran and the green manure, because the injuries inflicted by them on the young plants had weakened the latter so much that they did not produce a sufficient number of accessory stems and were therefore unable to consume the whole of the nitrogen which became available in the course of the decomposition of these manures; the straw had injured the plants so much that they were unable to consume the whole of the nitrogen which became available in the soil, the proportion of nitrogen in the whole crop being smaller than that in the crop grown without any nitrogenous manure.

Although the general features of the assimilation-factors of the various nitrogenous fertilizers are similar to the rates of increase of hulled grain, we do not deem it proper to take them into account for our judgment on the manurial value of the fertilizers for rice. The proportion of nitrogen which enters the crops, is not necessarily connected with the production of grain or organic matter at all. Much depends on the period of growth during which the nitrogen becomes available; too early and too late a consumption of the nitrogen by the crop alike unfavorable to the formation of grain. If much nitrogen is available in the beginning of the season the plants will send up numerous shoots which in a later period have, as a matter of course, an increased demand for nitrogenous food to complete their growth; if then the nitrogen of the manure has already been exhausted, the final development of the plants will be less complete, and the general result will be a production of much straw and little grain. On the other side, if in the beginning of growth only a little nitrogen can be consumed and about the flowering time much, the plants will still take up that nitrogen and deposit it chiefly in the straw, but the quantity of the crop

is no longer materially affected. Thus the proportion of nitrogen consumed by a certain crop from a given supply in the manure cannot be regarded as an exact basis for the determination of the general effect of that manure *on the special crop* in view. Nevertheless it may give valuable information as to the exact time at which the nitrogen became available, if its relation to the yield of grain and straw, and the proportion between grain and straw, are considered together and at the same time. If we carry out such calculations in the present case we get the following results :

	Hulled grain, per cent of the whole crop.	Nitrogen in the dry matter of the whole crop.
		%
Without nitrogen	...34.1	0.90
Steamed bone dust ...	...33.0	0.91
Hoshika	...34.1	0.91
Shimekasu	...34.1	0.96
Blood meal	...35.3	0.98
Crude bone dust	...33.7	0.92
Shōchū cake	...32.3	0.88
Horn meal	...35.2	0.94
Peruvian guano	...32.5	0.91
Shōyu cake	...34.3	0.93
Rape cake	...33.1	0.92
Night-soil	...32.5	0.90
Ammonium sulphate ...	...35.1	0.95
Farmyard manure ...	...34.1	0.90
Rice bran	...35.5	0.92
Green plants	...34.4	0.90

The variations caused by the different fertilizers as regards the percentage of hulled grain in the whole crop as the percentage content of nitrogen, are so insignificant that in all the special trials the nitrogen of the manures appears to have displayed its full effect.

Finally, it may be of some interest to calculate how much nitrogen and phosphoric acid was required in the preceding researches for the production of one *koku* of hulled grain. The results are thus :

A. Nitrogen.

	Kwamme.		Kwamme.
Steamed bone dust	...1.13	Peruvian guano ...	...1.43
Hoshika	...1.20	Night-soil	...1.57
Shimekasu	...1.21	Shōyu cake	...1.59
Blood meal	...1.31	Rape cake, fresh ...	...1.59
Crude bone dust ...	...1.35	Ammonium sulphate	...1.62
Shōchū cake ...	...1.35	Farmyard manure	...1.90
Horn meal	...1.39	Rice bran, unfermented.	2.99[23]

B. Phosphoric Acid.

	Kwamme.
Superphosphate	...0.75
Precipitated calcium phosphate	...0.70
Bone dust	...1.28
Thomas phosphate	...1.41
Peruvian guano	...2.19
Bone ash	...2.66
Phosphorite	...8.28

These figures have reference only to the increase of hulled grain over that quantity which the soil is capable of producing without any nitrogenous or phosphatic manure. In medium soils the supply of nitrogen to the crops from the residues of previous manures and from constituents of the soil itself, as well as from natural sources such as irrigation, rain, and fixation of atmospheric ammoniacal and nitric compounds is generally very large, exceeding considerably the amount of nitrogen applied in the manure. Compared with the nitrogen supply there exists, especially in Japanese soils, which never

23 In the fermented state about 1.60 kwamme of nitrogen.

received any special phosphatic fertilizer, far less available phosphoric acid than is needed to secure the full action of the available nitrogen. Judging from our experiments, the proportion of 1 part of available nitrogen to 2 parts of available phosphoric acid which is recommended by P. Wagner[24] for cereals, is *in general* also the best suited for paddy rice. With this proportion it is intended not only to cover just the needs of the crop, but at the same time to enrich gradually the soil with phosphatic compounds.

---

24 Important practical questions on the subject of manures, 1885, p. 36-67; see bulletin No. 3, p. 23.

Yield of the Single Plots

No. of plot.		Straw. grms.	Full grain. grms.	Empty grain. grms.
	I. Series. Unmanured, Partial and Complete Manure.			
8	Unmanured	323.5	291.6	2.4
32	"	379.5	313.2	2.3
61	"	273.0	226.3	1.7
9	Without nitrogen	465.0	359.6	2.8
23	" "	606.5	465.7	3.5
11	Without phosphoric acid	338.0	276.9	2.9
35	" " "	378.0	249.9	2.2
10	Without potash	809.5	578.3	7.7
34	" "	730.5	598.8	8.7
12	Complete manure	910.0	636.7	11.3
36	" "	997.5	649.7	7.3
65	" "	1017.5	628.0	4.2
	II. Series. Effect of Unrecovered Phosphoric Acid.			
27	3.65 grms. unrecovered P_2O_5 ..	329.0	243.5	3.7
37	" " " " ..	321.0	236.5	2.9
42	" " " " ..	430.5	336.2	3.4
28	6.99 grms. unrecovered P_2O_5 ..	339.0	262.5	3.1
38	" " " " ..	383.0	262.0	5.8
43	" " " " ..	362.5	282.5	2.7
29	10.86 grms. unrecovered P_2O_5 ..	477.0	425.0	3.0
39	" " " " ..	563.0	441.0	3.7
44	" " " " ..	460.5	361.0	4.3
30	14.81 grms. unrecovered P_2O_5 ..	605.0	476.0	2.5
45	" " " " ..	574.0	480.0	2.3
55	19.32 grms. unrecovered P_2O_5 ..	713.0	534.2	12.3
17	" " " " ..	722	453.9	4.6
24	" " " " ..	730.5	584.1	6.7
31	23.29 grms. unrecovered P_2O_5 ..	700.5	606.8	7.2
41	" " " " ..	746.0	612.8	6.7
46	" " " " ..	673.0	542.5	13.0

Yield of the Single Plots *(continued)*.

No. of plot.		Straw. grms.	Full grain. grms.	Empty grain. grms.
	III. Series. Action of Genge.			
7	No lime	683.0	487.0	3.9
19	,, ,, ...	562.5	443.5	4.5
26	,, ,, ...	623.0	462.0	4.3
57	20 kilogrms. CaO per tan	828.0	657.0	4.8
56	,, ,, ,, ,, ,, ...	920.5	639.0	6.3
70	,, ,, ,, ,, ,, ...	761.0	605.0	4.6
52	30 kilogrms. CaO per tan	820.5	631.5	5.3
66	,, ,, ,, ,, ,, ...	853.0	625.0	5.9
71	,, ,, ,, ,, ,, ...	801.5	592.5	5.1
53	40 kilogrms. CaO per tan	759.0	580.5	4.1
67	,, ,, ,, ,, ,, ...	916.5	657.0	3.4
76	,, ,, ,, ,, ,, ...	905.5	701.0	6.1
	IV. Series. Effect of Various Phosphates.			
1	No phosphoric acid	408	307.5	2.4
20	,, ,, ,, ...	316	211.2	3.2
39	,, ,, ,, ...	394	271.5	4.3
12	Sodium phosphate, single dose ..	581	464.0	5.7
21	,, ,, ,, ,, ..	428	316.0	6.7
40	,, ,, ,, ,, ..	433	344.0	4.1
3	,, ,, double dose ..	637	534.5	4.6
22	,, ,, ,, ,, ..	661	531.5	7.3
41	,, ,, ,, ,, ..	637	523.5	5.1
4	Double Superphosphate, single dose	751	554.0	8.0
23	,, ,, ,, ,,	632	483.0	5.7
42	,, ,, ,, ,,	570	482.0	9.9
5	,, ,, double dose	789	605.0	15.9
24	,, ,, ,, ,,	674	551.5	6.2
43	,, ,, ,, ,,	835	682.5	5.6

Yield of the Single Plots *(continued).*

No. of plot.		Straw. grms.	Full grain. grms.	Empty grain. grms.
25	Precipitated phosphate, single dose	715	570.5	8.0
44	,, ,, ,, ,,	707	558.5	6.0
26	,, ,, double dose	863	664.5	10.8
45	,, ,, ,, ,,	939	685.5	15.0
27	Peruvian guano, single dose	525	402.0	4.4
46	,, ,, ,, ,, ...	608	415.5	4.7
9	,, ,, double dose	642	450.0	5.4
28	,, ,, ,, ,, ...	651	463.0	5.3
47	,, ,, ,, ,, ...	571	456.0	5.7
10	Thomas phosphate, single dose ..	546	417.5	6.5
29	,, ,, ,, ,, ..	706	530.5	5.6
48	,, ,, ,, ,, ..	628	476.0	5.2
11	,, ,, double dose ..	686	553.0	5.4
30	,, ,, ,, ,, ..	832	608.5	13.6
49	,, ,, ,, ,, ..	838	583.0	12.2
12	Steamed bone dust, single dose ..	618	487.5	14.5
31	,, ,, ,, ,, ,, ..	609	489.0	6.0
50	,, ,, ,, ,, ,, ..	730	594.5	5.9
3	,, ,, ,, double dose ..	800	592.5	15.3
32	,, ,, ,, ,, ,, ..	696	578.0	8.1
51	,, ,, ,, ,, ,, ..	966	755.0	14.5
14	Crude bone dust, single dose	633	419.0	9.2
33	,, ,, ,, ,, ,, ...	706	569.5	9.2
52	,, ,, ,, ,, ,, ...	650	500.0	12.6
15	,, ,, ,, double dose	913	721.0	10.2
34	,, ,, ,, ,, ,, ...	993	753.5	21.8
53	,, ,, ,, ,, ,, ...	869	667.0	18.8
16	Bone ash, single dose	458	340.0	2.8
35	,, ,, ,, ,, ...	570	431.0	6.3
54	,, ,, ,, ,, ...	479	402.0	5.5
17	,, ,, double dose	669	522.5	5.2
36	,, ,, ,, ,, ...	649	511.0	5.2
55	,, ,, ,, ,, ...	645	530.0	6.5

Yield of the Single Plots *(continued)*.

No. of plots.		Straw. grms.	Full grain. grms.	Empty grain. grms.
18	Phosphorite, single dose	418	337·5	3·0
37	,, ,, ,, ...	410	300.5	3·5
19	,, double dose	371	303·5	2.7
57	,, ,, ,, ...	397	325·0	3·1
	V. Series. Effect of Various Nitrogenous Manures.			
1	Without nitrogen	604	392·3	4.6
36	,, ,, ...	501	350·3	3·0
71	,, ,, ...	578	431.8	2.5
19	,, ,, ...	596	496.2	2.8
54	,, ,, ...	623	456.4	2.6
89	,, ,, ...	772	579·5	3·5
37	Ammonium sulphate, single dose	666	466.7	3·3
72	,, ,, ,, ,,	753	635·2	6.8
38	,, ,, double dose	811	547·3	5·7
73	,, ,, ,, ,,	952	637·4	12.6
39	Night-soil, single dose	824	519·1	2.9
74	,, ,, ,, ,, ...	811	588.6	8.4
40	,, ,, double dose	816	560.1	6.0
75	,, ,, ,, ,, ...	999	610.1	9.8
41	Shime kasu, single dose	724	535·1	4·9
76	,, ,, ,, ...	831	634.8	7·2
7	,, double dose	826	699.5	9·5
42	,, ,, ,, ...	773	605.1	8.9
77	,, ,, ,, ...	992	712.6	11.4
8	Hoshika, single dose	710	583.6	4·4
43	,, ,, ,, ...	656	520.3	5.6
78	,, ,, ,, ...	937	653.6	6.4
9	,, double dose	773	633·5	6.4
44	,, ,, ,, ...	776	590.6	5·1
79	,, ,, ,, ...	898	693·9	10.1

Yield of the Single Plots *(continued).*

No. of plot.		Straw. grams.	Full grain. grms.	Empty grain. grms.
45	Blood meal, single dose	718	531.7	3.3
80	,, ,, ,, ,, ...	747	620.5	10.5
46	,, ,, double dose	820	608.4	5.6
81	,, ,, ,, ,, ...	828	608.3	9.7
47	Flesh meal, single dose	727	540.2	4.8
82	,, ,, ,, ,, ...	629	449.8	3.2
13	,, ,, double dose	771	568.6	4.4
48	,, ,, ,, ,, ...	819	600.6	5.4
83	,, ,, ,, ,, ...	716	549.9	4.1
14	Steamed bone dust, single dose ..	840	601.4	5.6
49	,, ,, ,, ,, ,, ..	941	622.7	8.3
84	,, ,, ,, ,, ,, ..	772	556.6	7.4
15	,, ,, ,, double dose.	989	621.5	4.5
50	,, ,, ,, ,, ,,	1041	717.3	4.6
85	,, ,, ,, ,, ,,	988	723.5	6.5
16	Crude bone dust, single dose ..	866	617.3	5.7
51	,, ,, ,, ,, ,, ..	769	537.0	7.0
86	,, ,, ,, ,, ,, ..	939	558.2	6.8
17	,, ,, ,, double dose ..	1026	702.9	7.1
52	,, ,, ,, ,, ,, ..	905	619.3	5.7
87	,, ,, ,, ,, ,, ..	1062	716.0	8.0
18	Peruvian guano	935	654.8	10.2
53	,, ,, ...	827	573.9	9.1
88	,, ,, ...	935	612.1	15.2
20	Farmyard manure, single dose ..	644	484.4	3.6
55	,, ,, ,, ,, ..	692	506.7	4.3
90	,, ,, ,, ,, ..	889	646.0	6.0
21	,, ,, double dose.	727	557.0	4.0
56	,, ,, ,, ,,	788	555.1	2.9
91	,, ,, ,, ,,	853	630.4	4.6
22	Green plants, single dose	528	437.1	3.9
57	,, ,, ,, ,, ...	657	465.8	4.2
92	,, ,, ,, ,, ...	811	587.6	4.4
23	,, ,, double dose	591	503.9	5.1
58	,, ,, ,, ,, ...	654	513.0	5.0
93	,, ,, ,, ,, ...	788	639.6	7.4

Yield of the Single Plots *(continued)*.

No. of plots.		Straw. grms.	Full grain. grms.	Empty grain. grms.
24	Rice bran, single dose	554	431·9	3·1
59	,, ,, ,, ,, ...	682	539·2	5·3
94	,, ,, ,, ,, ...	685	544·3	3·7
25	,, ,, double dose	569	473·6	3·6
60	,, ,, ,, ,, ...	710	576.7	6.2
95	,, ,, ,, ,, ...	830	597·1	10.9
26	Rape cake, single dose	676	521.3	4·7
61	,, ,, ,, ,, ...	766	539·3	7·7
96	,, ,, ,, ,, ...	887	594·8	10.2
27	,, ,, double dose	747	544·2	2.8
62	,, ,, ,, ,, ...	962	628.0	5.0
97	,, ,, ,, ,, ...	1003	699.0	6.3
28	Shōyu cake, single dose	647	493·4	4.6
63	,, ,, ,, ,, ...	815	604.4	6.1
98	,, ,, ,, ,, ...	764	560.8	7·7
29	,, ,, double dose	733	542.2	5.8
64	,, ,, ,, ,, ...	906	642.7	5·3
99	,, ,, ,, ,, ...	847	618.2	9.6
30	Shōchū cake, single dose	825	577·1	4·9
65	,, ,, ,, ,, ...	868	598.1	6.4
100	,, ,, ,, ,, ...	858	534·9	4.6
31	,, ,, double dose	885	655·9	6.1
66	,, ,, ,, ,, ...	908	660.0	9·5
101	,, ,, ,, ,, ...	987	673.0	7·5
32	Horn meal, single dose	776	554·9	9.6
67	,, ,, ,, ,, ...	667	546.7	5·7
102	,, ,, ,, ,, ...	734	600.2	5·3
33	,, ,, double dose	741	581.7	4·3
68	,, ,, ,, ,, ...	734	557·3	5·2
103	,, ,, ,, ,, ...	755	662.3	7·2
34	Straw, single dose	487	409·3	3·7
69	,, ,, ,, ...	505	431.0	2.5
35	,, double dose	482	409·4	6.6
70	,, ,, ,, ...	481	370.0	4.0
105	,, ,, ,, ...	564	452.2	3.8

ERRATA.

Bulletin No. 9.

Page 13, table, second line from top, read dry matter after 6 weeks 61.38, instead of 31.38.

Bulletin No. 10.

Page	6,	4th	line from bottom, read 3.75, instead of 3.02.
,,	6,	2nd	line from bottom, read 3.04, instead of 3.77.
,,	7,	3rd	line from top, read 4.90, instead of 6.06.
,,	11,	12th	line from top, read 4.9, instead of 6.1.

農科大學
學術報告
第十一號

IMPERIAL UNIVERSITY.

College of Agriculture.

(FORMERLY COLLEGE OF AGRICULTURE AND DENDROLOGY).

KOMABA, TŌKYŌ, JAPAN.

BULLETIN No. 11.

Manuring Experiments with Paddy Rice.

(Third Year.)

Communicated

BY

DR. O. KELLNER,

Professor of Agricultural Chemistry.

明治二十五年七月

TŌKYŌ, KOMABA, JULY, 2552 (1892).

PRINTED BY HAKUBUNSHA, GINZA, TŌKYŌ.

Manuring Experiments with Paddy Rice.
(Third Year, 1891.)

BY

Dr. O. Kellner, Y. Kozai, Y. Mori, and M. Nagaoka.

Some of the experiments on rice commenced in 1889 and 1890,[1] were continued last year, partly to study the exhaustion of soil nutrients by successive crops, and partly to ascertain the after-action of various phosphates applied in the preceding seasons.

The experiments were carried out in the same fashion as in the preceding years. After cutting the rice in November 1890, the plots, which comprised an area of 3 square feet surrounded by a deep wooden frame, were left untouched till the following April, when the soil was turned. In the beginning of June they were irrigated and converted into a fine mud, all lumps being well crushed. In the mean time young rice plants of the variety known as "*koniwa*" which has a medium length of vegetation had been raised in the usual way in a seed bed and were transplanted after manuring the plots. Each frame received 192 healthy plants altogether in 16 bundles of 12 each. Irrigation was at once commenced, the water being furnished, as formerly, from small tanks of a capacity of about 70 litres which were placed on the northern sides of the frames and kept constantly filled with water. As to the conditions of the soil and water, reference may be made to bulletin No. 8 (p. 3—5).

In the course of the season the weeds were destroyed several times in the usual way, the irrigation having been stopped for

---

1 Bulletin No. 10, Imperial University, College of Agriculture.

1—2 days and the water allowed to drain off from the plots. Towards the end of September the irrigation was discontinued, and water was afterwards given only for two days when the rice was in blossom. The weather, though not so very favorable as in 1890, continued to be good throughout the season; no injuries were noticed, and the yield in our vicinity was in general regarded as medium good. On the 10th of November the rice was cut and dried in the air.

Each trial was carried out in triplicate.

I. Series. Researches on the exhaustion of soil nutrients (nitrogen, phosphoric acid, and potash) in the third year.

Carried out in conjunction with
S. Uchiyama and *T. Yamada.*

These experiments were carried out on 15 plots divided into 5 groups of 3 plots each, which had already served for the same purpose in the two preceding years. Our intention was, as already stated, to ascertain the quantity of each of the three essential nutrients which the soil may yield to rice on plots not supplied with the respective nutrients but manured with the other essential ingredients of plant food. The supply of fertilizers was as follows (per *tan* = 0.0992 hectare):

1) 3 plots were left *unmanured.*

2) 3 plots did not receive any *nitrogenous* manure, but were supplied with much phosphoric acid (10 kilogrms.) and potash (10 kilogrms.).

3) 3 plots reveived a manure free from *phosphatic* ingredients but rich in nitrogen (10 kilogrms.) and potash (10 kilogrms.).

4) 3 plots were not supplied with *potash*, but received much nitrogen (10 kilogrms.) and phosphoric acid (10 kilogrms.).

5) 3 plots received a *complete* manure containing 10 kilogrms. nitrogen, 10 kilogrms. phosphoric acid, and 10 kilogrms. potash.[2]

In all these experiments the nitrogen was applied in the form of ammonium sulphate, the phosphoric acid as double superphosphate, and the potash as carbonate.

The development of the crops was exactly the same as in the two preceding years; those plants which had received a complete manure were the strongest from the beginning to the end of the season, they suffered least from transplantation, and exhibited a normal green colour; compared with them the plants without potash were noticeably inferior, the difference becoming perceptible as early as the middle of July; next in order were those without nitrogen which, however, turned light green and pale at an early period, and ripened a little earlier; those which had not been supplied with phosphatic food did not differ essentially from the unmanured plants; though of a deep green colour they remained very small, and ripened late.

The yield of grain and straw of the single plots will be found in the appendix. In the average of three equally manured plots we obtained the following produce:

	Straw. grms.	Full grain grms.	Empty grain. grms.	Whole crop. grms.
Unmanured..	289.7	213.1	3.0	505.8
Without nitrogen	476.0	341.3	4.9	822.2
,, phosphoric acid..	371.0	270.6	5.0	646.6
,, potash	630.3	414.8	11.0	1056.1
Complete manure	780.3	575.9	9.2	1365.4

These results coincide in their main features very well with those obtained in the 2 preceding years, which, for the sake of comparison, may be quoted here:

2 As the same nutrients had been applied in liberal doses in the 2 preceding years, the above quantities were amply sufficient for a maximum produce.

	Straw. grms.	Full grain grms.	Empty grain.. grms.	Whole crop. grms.
1889; variety *Satsuma.*				
Unmanured..	197	106.4	6.5	309.9
Without nitrogen	459	367.3	15.3	841.6
,, phosphoric acid...	193	89.7	6.5	289.2
,, potash	714	564.0	23.8	1301.8
Complete manure	832	575.1	31.1	1438.2
1890; variety *Shiratama.*				
Unmanured..	325	277.0	2.1	604.1
Without nitrogen	536	412.7	3.2	951.9
,, phosphoric acid...	358	260.9	2.6	621.5
,, potash	770	582.5	8.2	1360.7
Complete manure	975	638.1	7.6	1620.7

In the three experimental years the lowest yield was invariably obtained on the unmanured and those plots which had not received any phosphatic fertilizer, and this result proves that in our soil the phosphoric acid is in the relative minimum among the three essential nutrients. Then follow the plots which were not supplied with nitrogen; though the stock of this nutrient in our soil suffices for a considerable produce, it does not provide enough for the maximum yield. The quantity of soil potash, too, is not sufficient for the highest obtainable produce, but of the three nutrients under discussion its proportion is the largest.

Comparing the yields of the three years we do not find great regularity, the produce of 1890 exceeding in general that of the two other seasons. This difference is, however, simply explained by the differences of the weather, variety, and particularly by the condition of the plants brought up in the seed bed which, in 1890 were about three times as large and heavy as in the two other seasons; this is seen in the following record on the content of the young plants per plot:

	1889.	1890.	1891.
Dry matter	..20.55 grms.	62.66 grms.	19.00 grms.
Nitrogen..	.. 0.366 ,,	1.774 ,,	0.364 ,,
Phosphoric acid	.. 0.087 ,,	0.334 ,,	0.073 ,,
Potash	.. 0.192 ,,	0.653 ,,	0.245 ,,

As the plants of 1890 were richer in nutrients than those of the two other seasons, their development was, of course, also better, especially on those plots which did not receive these nutrients in the manure.

Concerning the quantities of *nitrogen* consumed from the soil and manure we found the following results :

	Nitrogen in the dry matter of the whole crop.		Nitrogen in the manure.	Nitrogen extracted from the soil, resp. soil and manure.
	%	grms.	grms.	grms.
Unmanured,	1889..1.435	3.84	0	3.47
,,	1890..1.078	5.66	0	3.89
,,	1891..1.130	5.01	0	4.65
Without nitrogen,	1889..1.054	7.54	0	7.17
,, ,,	1890..0.937	7.43	0	5.66
,, ,,	1891..0.893	6.39	0	6.03
Complete manure,	1889..1.096	13.37	9.18	13.00
,, ,,	1890..0.943	12.46	9.18	10.69
,, ,,	1891..1.002	11.93	8.33	11.57

When considering these results we should keep in mind that our soil is rich in nitrogen, containing in its dry matter 0.49%. Hence the supply from the soil on the unmanured plots was still so large in the third year that the other essential nutrients of the soil did not suffice to enable the plants to make full use of the nitrogen consumed ; the crop became therefore richer in nitrogen than even on the plots liberally manured with ammoniacal salts. On the plots which had received phosphatic and potassic but no nitrogenous manure the crop was the poorest in

nitrogen because the stock of this nutrient in the soil, though very considerable, was not sufficient to secure a maximum crop. In 1890 there were consumed from the natural sources (soil, atmosphere, and water of irrigation) 5.66 grms. nitrogen per frame, in 1891 6.03 grms. i.e. practically the same quantity. Should this result be confirmed in the coming seasons, we should be entitled to conclude that under the conditions of our farm, paddy rice is capable of consuming 5.85 grms. of nitrogen per plot=7.02 kilogrms. per *tan*. As according to former researches of ours, 62.2% of medium quantities of ammoniacal nitrogen enter the rice crop, the natural supply pro anno would be equal to 11.29 kilogrms. of ammoniacal nitrogen per *tan*, and would suffice for the production of 1.85 *koku*[3] of hulled grain.

On the plots supplied with complete manure the following quantities of nitrogen applied in the form of ammonium sulphate entered the crop (in grms. per plot):

	1889.	1890.	1891.
In the whole crop	13.37	12.46	11.93
In the crop grown without nitrogenous manure.	7.54	7.43	6.39
Taken up from the manure	5.83	5.03	5.54
Applied in the manure	9.18	9.18	8.33
Taken up, per cent of the nitrogen applied	63.0	54.8	66.5

Thus in the average of the three years' experiments carried out on the same plots, we find an "assimilation-factor" of 61.4 for ammoniacal nitrogen, which figure is very near to the result of the experiments of 1889 on other plots with various quantities of ammonium sulphate from which 62.2% had been recovered in the crop.

As to the assimilation of the *phosphoric acid* our researches gave the following results.

3 1 *Koku*=180.39 litres.

	Phosphoric acid in the dry matter of the whole crop.		Phosphoric acid in the manure.	Phosphoric acid taken up from the soil, resp. from soil & manure.
	°/°	grms.	grms.	grms.
Unmanured,	1889..0.240	0.64	0	0.55
,,	1890..0.165	0.86	0	0.53
,,	1891..0.180	0.80	0	0.73
Without phosphoric acid,	1889..0.232	0.61	0	0.52
,, ,, ,,	1890..0.165	0.88	0	0.55
,, ,, ,,	1891..0.171	0.96	0	0.89
Complete manure,	1889..0.320	4.12	18.36	4.03
,, ,,	1890..0.206	2.73	18.36	2.40
,, ,,	1891..0.220	2.62	8.33[4]	2.55

The figures for the phosphoric acid assimilated from the soil of the unmanured plots and those which had received all nutrients except phosphoric acid, indicate that the disintegration and decomposition of the phosphatic constituents of the soil originally inaccessible to the roots, gradually commence on a rather large scale. Our soil is very rich in phosphoric acid (0.49%), but as it consists chiefly of recent volcanic products, it is not yet sufficiently decomposed to yield much of the latter nutrient to crops. The repeated mechanical treatment of the soil which had been left uncultivated for several years before the experiments were commenced, and the indirect action of the ammonium sulphate and potassium carbonate on the plots without phosphoric acid, are probably the principal reasons for the slight increase of the assimilability of the phosphatic soil ingredients. In the average of the three years the quantity of phosphoric acid consumed from the soil amounted to 0.60 grms. per frame=0.72 kilogrms. per *tan* on the unmanured plots, and to 0.65 grms. per frame=0.78 kilogrms. per *tan* on the plots

4 As these plots had received in 1890 a large dose of phosphoric acid we applied less of it in 1891.

without phosphoric acid; assuming 20% of the phosphoric acid of superphosphates to be assimilable to the first crop, the stock available in the soil per *tan* would be equivalent to 3.6 resp. 3.9 kilogrms. of phosphoric acid soluble in water, and would suffice only for the production of 1.2—1.3 *koku* of hulled rice.

Lastly, with reference to the consumption of *potash* from the soil our researches gave the following results:

	Potash in the dry matter of the whole crop.		Potash in the manure.	Potash consumed from the soil, resp. soil and manure.
	%	grms.	grms.	grms.
Unmanured,	1889..0.705	1.89	0	1.70
,,	1890..0.886	4.65	0	4.00
,,	1891..0.595	2.64	0	2.39
Without potash,	1889..0.429	4.78	0	4.59
,, ,,	1890..0.386	4.32	0	3.67
,, ,,	1891..0.341	3.14	0	2.89
Complete manure,	1889..0.710	9.25	9.18	9.06
,, ,,	1890..0.770	10.17	9.18	9.52
,, ,,	1891..0.660	7.85	8.33	7.60

The percentage content of the crops, as well as the total quantity of potash extracted from the soil, clearly shows that in consequence of the continued cultivation of rice the stock of assimilable potash in the soil diminished so far that maximum crops could no longer be produced in 1890 and 91 unless this nutrient were supplied in the manure. Assuming according to our preceding researches (bulletin No. 8) that of the assimilable potash of the soil 50% can be consumed by the rice plants, we find the total assimilable potash to have amounted:

	per frame	per tan
in 1889	9.18 grams.	11.0 kilogram.
,, 1890	7.34 ,,	8.8 ,,
,, 1891	5.78 ,,	6.9 ,,

The results of the two last years have now enabled us to find out how much assimilable potash must be contained in the soil for the production of 1 *koku* of hulled rice.[5] The total quantity of potash in the harvested materials was per frame 4.32 resp. 3.14 grms., hence per *tan* 5.19 resp. 3.77 kilogrms. which correspond to 10.38 resp. 7.54 kilogrms. of total assimilable potash in the soil. The yield of hulled grain amounted to 3.97 resp. 2.82 *koku*, hence the proportion of assimilable potash required for the production of 1 *koku* was in 1890 2.62 and in 1891 2.67 kilogrms.[5]

In connection with the preceding researches we also ascertained the influence of the various manures on the composition of the straw and hulled grain. The analysis of the crop of 1890 made in conjunction with *S. Uchiyama* and *T. Yamada*, graduates of the College, gave the following results:

5 The quantities of nitrogen and phosphoric acid necessary for the production of 1 *koku* hulled grain have already been given in bulletin No. 10, p. 42.

A. Straw.

	Complete manure.	Without potash.	Without phosphoric acid.	Without nitrogen.
	%	%	%	%
Moisture	20.92	19.98	15.70	18.54
In 100 parts of dry matter:				
Crude protein	4.57	4.86	5.29	3.84
,, fibre	33.36	34.98	32.15	33.43
,, fat	1.85	1.77	1.56	1.79
Nitrogen-free extract	40.87	41.73	39.98	42.14
Ash (free from C and CO_2).	19.35	16.66	21.02	18.80
Total nitrogen	0.731	0.779	0.845	0.615
Albuminoid nitrogen	0.679	0.659	0.746	0.482
Non-albuminoid nitrogen ..	0.052	0.120	0.099	0.133
do., per cent of total nitrogen.	7.1	15.5	11.7	21.6

When considering these results we should take into account that the season of 1890 was very favorable to the development of rice and that the crops when they were cut had attained a normal maturity with the only exception of the plots which had not been manured with phosphoric acid; on the latter the straw was still green at the time of harvesting.

In the above table on the composition of the straw we notice some differences in proportion of crude protein and ash. The largest content of crude protein is found in the straw produced by means of a rich nitrogenous and potassic manure from which much nitrogen entered the plants but could not be fully used up for the production of organic matter because of the deficiency of phosphoric acid; the lowest proportion exists in the straw raised without any nitrogen in the manure because in these plants the insufficient quantity of nitrogen consumed

from the soil and water, was worked up as completely as possible. As to the content of ash we notice the largest proportion in the straw without any phosphoric acid in the manure, next follows that without nitrogen, and finally comes that without potash; in these three experiments the whole produce ranges in inverse order, the smallest crop (without phosphoric acid) being thus the richest in ash, the largest one (without potash) the poorest, while the straw produced with a complete manure, in which case the yield was the largest, occupies a medium position as to the content of ash. The reasons for these differences are plain, small crops having at their disposal more of the mineral manure than large ones, and the crop with complete manure receiving a little more mineral matter than that without potash.

The analyses of the ash of the 4 kinds of straw gave the following results:

In 100 parts of ash.	Complete manure.	Without potash.	Without phosphoric acid.	Without nitrogen.
Potash	5.19	**1.45**	5.03	5.91
Soda	0.94	**2.33**	0.60	2.05
Lime	1.01	1.25	1.15	1.30
Magnesia	0.68	0.98	0.77	0.25
Ferric oxide	2.63	3.33	1.35	2.23
Phosphoric acid	0.37	0.45	**0.16**	0.36
Sulphuric acid	0.99	0.81	0.85	0.32
Silica	87.08	88.72	88.92	86.45
Chlorine	1.74	1.26	2.03	2.00

Compared with the composition of the ash of the straw from the plots with a complete manure we find the lowest proportion of potash and the largest content of soda in the case in which the manure was free from potash. Soda is capable of substi-

tuting potash to some extent, a fact frequently noticed in ash analyses and recently announced by P. Wagner to have also some practical importance on the yield of crops. The straw from the plots not supplied with phosphoric acid, is the poorest in this nutrient, as we have already stated (bulletin 8, p. 30); and on the plot without nitrogen a smaller amount of sulphuric acid entered the straw than in the other cases, because the manure applied did not contain any ammonium sulphate, in which form the other plots received their nitrogen.

B. Grain.

The grain harvested on the plots of series I differed remarkably in quality. According to the judgment of experts the grain from the unmanured plots was the best, it resembled *Sekitori-mai*, one of the best kinds of Japanese rice, produced in the province of Ise; the grains were uniform in shape, large in size, and had a fine lustre and a smooth surface without any spots or wounds. Only a little inferior to these was the grain from the plots which had not received any phosphatic fertilizer. Next in order of quality was the grain produced with the help of the complete manure; then followed that obtained on the plots left without potash. The grain produced without any nitrogenous manure was of the poorest quality, resembling *Akita-mai* a most inferior kind, produced in the north of the main island in Akita prefecture; the grains from these plots had a dark colour, numerous white spots and wounds on their surface, and were very brittle.

The weight of 1000 grains obtained in this series, was as follows (in grms.):

	Unhulled grain.	Hulled grain.	Chaff.	Chaff, per cent of unhulled grain.
Unmanured	32.08	26.61	5.47	17.0
Without phosphoric acid.	30.77	25.47	5.30	17.2
,, potash	28.56	23.69	4.87	17.0
,, nitrogen	30.76	25.43	5.33	17.3
Complete manure	28.68	23.78	4.90	17.1

The percentage composition of the hulled grain was as follows:

	Complete manure.	Without potash.	Without phosphoric acid.	Without nitrogen.
	%	%	%	%
Moisture	15.33	14.99	15.37	15.25
In 100 parts of dry matter:				
Crude protein	10.82	10.46	12.81	9.60
„ fibre	1.12	1.10	1.01	0.99
„ fat	2.78	2.53	2.41	2.33
Nitrogen-free extract	84.22	84.71	82.93	85.67
Ash	1.06	1.20	0.84	1.41
Total nitrogen	1.731	1.673	2.050	1.536
Albuminoid nitrogen	1.683	1.615	1.805	1.272
Non-albuminoid nitrogen ..	0.048	0.058	0.245	0.264
do., per cent of total nitrogen.	2.8	3.5	11.3	17.2
In 100 parts of ash:				
Potash	24.75	22.11	26.10	28.63
Lime	2.50	1.77	2.49	1.44
Ferric oxide	0.71	0.42	0.59	0.54
Phosphoric acid	50.03	48.38	40.51	53.13
Silica	5.36	4.36	4.44	3.74
Chlorine	2.61	2.20	2.95	1.26

Upon comparing these figures with the order of the quality of the 4 kinds of grain, we notice that the content of crude protein well bears out the judgment on the quality formerly

quoted. The grain richest in nitrogenous substances was the best. Other analyses made in our laboratory seem to confirm that this observation has a somewhat general character.

It is somewhat surprising to find among the nitrogenous constituents the largest fraction of non-albuminous substances in the grain from the plots without nitrogen. Just in this crop we might have anticipated that we should find the smallest proportion of non-albuminous nitrogenous compounds because of the small nitrogen supply which we should assume to be greatly needed for the production of albuminoids. As the same result was, however, obtained also in the analysis of the straw, we must lay some stress upon it, hoping to be able to further investigate this subject with the crops of the subsequent seasons.

In the ash of the 4 kinds of grain we find similar differences as in the case of straw. Wherever one of the essential mineral nutrients had been withheld from the manure we find that nutrient also in the relative minimum proportion in the grain.

II. Series. After-Effect of Unrecovered Phosphoric Acid applied as Sodium Phosphate. (Third Year.)

The plots of this series received in 1889 various quantities of powdered sodium phosphate besides much nitrogen as ammonium sulphate and much potash as carbonate, and in order to ascertain how much of the phosphoric acid left by the crop of that year was still available in the subsequent seasons, we cultivated rice again on the same plots in 1890 and 1891, manuring them only with nitrogen and potash in the form of the same salts as before.[6] Thus in 1891 we applied per tan 10 kilogrms. of nitrogen and 10 kilogrms. of potash.

For the sake of comparison we may here also take into consideration the plots without phosphoric acid and those with a

6 Bulletin No. 10, p. 11.

complete manure (see this bulletin, p. 3). The proportions of phosphoric acid applied in 1889 and left unrecovered, as well as the produce in the third season, will be seen from the following table:

Phosphoric acid applied per frame in 1889.	Phosphoric acid not recovered.		Yield per plot in 1891.			
	in 1889.	in 1890.	Straw.	Full grain.	Empty grain.	Whole crop.
grms.	grms.	grms.	grms.	grms.	grms.	grms.
0	—	—	371	271	5	647
4.59	3.65	3.65	386	279	4	669
9.18	6.99	6.99	405	300	5	710
13.77	10.86	10.38	454	356	5	815
18.36	14.81	13.92	518	402	6	926
22.95	19.32	18.09	567	458	7	1032
27.54	23.29	21.73	561	459	7	1027
Complete manure.			780	576	9	1365

The phosphoric acid applied in 1889 had still, according to these results, a distinct effect on the crop of 1891. The yield of grain on the plot with the largest dose of phosphate was nearly twice as high as on the plots without phosphoric acid, but did not attain the figure obtained on the plot with complete manure, which included a fresh application of 8.33 grms. of phosphoric acid in the form of double superphosphate.

Similar were the results arrived at by the determination of the phosphoric acid consumed by these crops from the residues in the soil, as will be shown by the following figures:

Phosphoric Acid. Grms. per frame	1.	2.	3.	4.	5.	6.	Freshly manured.
In the whole crop of 1891	1.08	1.39	1.61	1.80	2.10	2.03	2.62
In the crop of 1891 produced without phosphoric acid.. ..	0.96	0.96	0.06	0.96	0.96	0.96	0.96
Consumed from the residual phosphoric acid	0.12	0.43	0.65	0.84	1.14	1.07	1.66
Residual phosphoric acid in 1891	3.65	6.99	10.38	13.98	18.09	21.73	—
Consumed, per cent of this residue	3.29	6.15	6.26	6.01	6.30	4.92	—

Now summing up the proportions of phosphoric acid consumed from the sodium phosphate applied in 1889, we arrive at the following figures:

	1.	1.	3.	4.	5.	6.
Phosphoric acid applied per frame in 1889, grms.. ..	4.59	9.18	13.77	18.36	22.95	27.54
Consumed, per cent of the phosphoric acid originally applied in 1889..	20.5	22.8	21.1	19.4	15.9	15.4
,, 1890..	—	—	3.5	4.5	5.4	5.7
,, 1891..	2.6	4.7	4.7	4.6	5.0	3.9
in the three years	23.1	27.5	29.3	28.5	26.3	25.0

These results clearly illustrate the well-known fact that easily soluble phosphates display their chief action soon after application, while in subsequent seasons the crops no longer derive any considerable benefit from them. It is probable that the experiments under discussion represent an extreme case, as they were made with an extremely soluble phosphate and on a soil very rich in hydrated sesquioxides of iron and aluminium, and consequently endowed with an extremely high absorptive power, in which medium the phosphoric acid applied is gradually converted into basic compounds not easily assimilable by plants.

III. Series. After-Effect of Various Phosphates. (Second Year).

This series was commenced in 1890 on 57 plots with 9 different kinds of phosphates, the composition and description

of which will be found in bulletin No. 10, p. 19. With each kind of manure 6 single trials were made, 3 with a small quantity of the respective phosphate, 3 with a large dose,—just double of the former.

The plots were left uncultivated till May 1891, when their soil was turned; in the middle of June they received all alike 10 kilogrms. of nitrogen as ammonium sulphate and 10 kilogrms. of potash as carbonate. The yield, average of 3 equally treated plots, was as follows:

Phosphoric acid per frame		Kind of phosphate.	Yield per frame.			
applied in 1890. grms.	not recovered in 1890 grms.		Straw grms.	Full grain. grms.	Empty grain. grms,	Whole crop. grms.
0	0	No phosphatic manure	394	274	4	672
3.89	2.95	Double Superphosphate	400	308	4	712
7.78	6.40	,, ,, ...	457	371	5	833
4.59	3.44	Precipitated Phosphate..	444	323	4	771
9.18	7.53	,, ,, ...	514	418	4	936
6.97	6.39	Peruvian Guano	519	396	4	919
13.94	13.07	,, ,, ...	593	460	6	1059
6.885	5.94	Thomas Phosphate	513	407	5	925
13.77	12.35	,, ,, ...	575	478	6	1059
6.885	5.91	Steamed Bone Dust	531	416	6	953
13.77	11.66	,, ,, ,, ...	627	517	6	1150
6.885	5.88	Crude Bone Dust	495	375	5	875
13.77	11.65	,, ,, ,, ...	574	454	5	1033
6.885	6.43	Bone Ash..	418	308	5	731
13.77	12.75	,, ,, ...	472	350	4	826
6.885	6.77	Phosphorite	423	314	4	741
13.77	13.69	,, ...	513	387	6	906

We see that in all the trials the unrecovered phosphoric acid had an influence on the succeeding crop ; the greatest after-effect was displayed by the steamed bone dust, next follow the Thomas phosphate, crude bone dust and Peruvian guano, then the precipitated phosphate, and finally come the phosphorite, double superphosphate, and bone ash. The differences are, of course, due not only to the kind of phosphate but also to the quantity of unrecovered phosphoric acid. In no case was the crop so large as that produced by means of a fresh application of 8.33 grms. of soluble phosphoric acid on the plots with a complete manure, in which trial the total yield amounted per frame to 1365 grms. and consisted of 575 grms. of full grain, 9 grms. of empty grain, and 780 grms. of straw.

The increase of full grain over the produce on the plots not supplied with any phosphate, was as follows (per frame):

Unrecovered phosphoric acid.	Kind of Phosphate	Increase per frame. 1891.	Increase caused	
			by 100 grms. of unrecovered phosphoric acid.	by 100 grms. of original phosphoric acid in the first season (1890).
grms.		grms.	grms.	grms.
2.95	Double Superphosphate.. ..	34	1153	6273
6.40	,, ,, ...	97	1516	5810
3.44	Precipitated Phosphate	49	1424	6689
7.53	,, ,, ...	144	1912	4510
6.39	Peruvian Guano	122	1908	2095
13.07	,, ,, ...	186	1423	1399
5.94	Thomas Phosphate	133	2240	3093
12.35	,, ,, ...	204	1652	2339
5.91	Steamed Bone Dust..	142	2393	3326
11.66	,, ,, ,, ...	243	2084	2768
5.88	Crude Bone Dust	101	1717	3763
11.65	,, ,, ,, ...	180	1545	3296
6.43	Bone Ash	34	529	1816
12.75	,, ,, ...	76	595	1874
6.77	Phosphorite	40	561	810
13.69	,, ...	136	826	363

The action of the unrecovered phosphoric acid on the yield in the second season was accordingly in all cases inferior to that of the freshly applied phosphate in the first season; the only exception being shown by the Peruvian guano which increased the crops in the two years for almost exactly the same amount. Particularly noticeable is the low action of the residual superphosphate and precipitated dicalcic phosphate which, as our results show, were converted to a large extent in the course of one year into an insoluble form not easily ac-

cessible to the roots. Even the bone ash and powdered phosphorite had less effect in the second season, though we might have anticipated that they would have become more active, as the richness of our soil in humus of a distinctly acid character favours the decomposition of insoluble calcic phosphate. The best after-effect was displayed, as already stated, by the two kinds of bone dust and the Thomas phosphate. The increase of grain caused by the residues of these manures in the second season amounts, in the case of steamed bone dust and Thomas phosphate, to about 70% of the increase in the first season, in the case of crude bone dust to nearly 50%.

In order to obtain definite figures as to the efficacy of the various phosphates in the *two seasons* we calculate from the preceding tables and from the results recorded in bulletin No. 10, p. 22 the following numbers, taking into account only the yields caused by the smaller doses of phosphoric acid, for the reasons formerly[7] given.

	Increase of grain in the two first seasons		Relative increase, action of superphosphate = 100	
	per plot grms.	caused by 100 grms. of phosphoric acid originally applied grms.	in the two seasons.	in the first season.
Double Superphosphate ..	274	7044	100	100
Precipitated Phosphate ..	356	7758	110.7	107.1
Peruvian Guano	268	3845	54.6	33.3
Thomas Phosphate	346	5025	71.2	48.8
Steamed Bone Dust.. ..	371	5388	76.5	53.0
Crude Bone Dust	360	5228	74.2	59.8
Bone Ash	159	2309	32.6	29.1
Phosphorite	96	1394	18.3	11.8

Before discussing these results we may take into account the quantities of phosphoric acid consumed from the residual phosphates. The chemical analyses of the crops gave the following results per frame :

7 Bulletin No. 10, p. 22.

Phosphoric acid applied in 1890. grms.	Phosphoric acid consumed in the first season (1890). %	Phosphoric acid left in the soil. grms.	Kind of phosphate.	Phosphoric acid, consumed from the residue.[8] grms.	Phosphoric acid, consumed from the residue.[8] %	Phosphoric acid, consumed from the original manure. Second season. %	Phosphoric acid, consumed from the original manure. First & second seasons. %	Phosphoric acid, consumed from the original manure. Average %
3.89	24.1	2.95	Double Superph.	0.158	5.3	4.1	28.2	26.5
7.78	17.7	6.40	,, ,,	0.556	8.7	7.1	24.8	
4.59	25.1	3.44	Precipitated Phos.	0.341	9.9	7.4	32.5	28.8
9.18	18.0	7.53	,, ,,	0.646	8.6	7.0	25.0	
6.97	8.3	6.39	Peruvian Guano.	0.451	7.1	6.5	14.8	13.9
13.94	6.3	13.07	,, ,,	0.935	7.1	6.7	13.0	
6.885	13.7	5 94	Thomas Phosph.	0.454	7.6	6.6	20.3	18.9
13.77	10.3	12.35	,, ,,	0.990	8.0	7.2	17.5	
6.885	14.2	5.91	Steamed Bone D.	0.392	6.6	5.7	19.9	20.9
13.77	15.3	11.66	,, ,, ,,	0.916	7.9	6.6	21.9	
6.885	14.6	5.88	Crude Bone Dust.	0.414	7.0	6.0	20.6	21.3
13.77	15.4	11.65	,, ,, ,,	0.900	7.7	6.5	21.9	
6.885	6.6	6.43	Bone Ash.	0.198	3.1	2.9	9.5	9.8
13.77	7.4	12.75	,, ,,	0.357	2.8	2.6	10.0	
6.885	1.7	6.77	Phosphorite.	0.155	2.3	2.2	3.9	3.6
13.77	0.6	13.69	,,	0.372	2.7	2.7	3.3	

The two preceding tables afford a sufficiently reliable basis for a judgment on the relative manurial action of the various phosphates displayed in the first two seasons. Assuming the assimilability of the phosphoric acid of the superphosphate (28.2%) to be 100, and calculating, on this basis, the relative assimilability of the other forms of phosphoric acid, we obtain the following figures:

8. After deducting 1.022 grms. of phosphoric acid which had been consumed from the soil ingredients.

	Assimilated from 100 parts of phosphoric acid originally applied. %	Relative assimilability in the two first seasons.	Relative assimilability in the first season.
Double Superphosphate ..	..28.2	100	100
Precipitated phosphate ..	..32.5	115.2	104.0
Crude Bone Dust..	..20.6	73.0	60.4
Steamed Bone Dust	..19.9	70.6	58.6
Thomas Phosphate	..20.3	72.0	56.9
Peruvian Guano	..14.8	50.2	34.4
Bone Ash	.. 9.5	33.7	27.4
Phosphorite	.. 3.6	13.6	7.1

The figures for the relative assimilability most satisfactorily coincide with the numbers for the relative increase of the crops. The following averages of the two series of results may accordingly be regarded as standards for the calculation of the quantities of various phosphates suited for rice under conditions similar to ours in respect to soil and climate.

	Relative manurial value in the first season	Relative manurial value in the first and second seasons.
Double Superphosphate..	..**100**	**100**
Precipitated Calcic Phosphate ..	..**106**	**113**
Crude Bone Dust	.. **60**	**74**
Steamed Bone Dust	.. **56**	**74**
Thomas Phosphate..	.. **53**	**72**
Peruvian Guano	.. **34**	**52**
Bone Ash	.. **28**	**33**
Phosphorite	.. **9**	**16**

The two years' experiments have shown that among the various phosphates experimented on, the *precipitated calcic phosphate* occupies the first rank in each of the two seasons; the first crop assimilated 25.1, the second 7.4% of the phosphoric acid applied in this form. Very similar, though a little inferior to the fertilizer is the *superphosphate* with an assimilation-factor of 24.1% in the first season and 4.1% in the second. Next in order of their action, follow the two kinds of *bone dust* and the *Thomas*

phosphate which are practically equal in effects in the first two seasons; on the first crop the crude bone dust acted the best, then followed the steamed bone dust, and finally the Thomas phosphate, but these differences were counterbalanced by a comparatively better action of the two latter manures on the second crop. The phosphoric acid of the *Peruvian guano*, though assimilated in both seasons to the same extent (8.3 resp. 6.3%), has a very slow effect, so that it would be better to convert it into superphosphate before application. The same must be stated as to the *bone* ash and *powdered phosphorite*.

Yield of the Single Plots.

No. of plot.		Straw. grms.	Full grain. grms.	Empty grain. grms.
	I. Series. Unmanured, Partial and Complete Manure.			
8	Unmanured	317	259	3.4
32	,, ...	271	206	2.9
61	,, ...	281	174	2.8
9	Without nitrogen..	448	287	4.2
33	,, ,, ...	440	339	4.9
62	,, ,, ...	540	398	5.5
11	Without phosphoric acid	416	328	4.0
35	,, ,, ,, ...	326	213	6.0
10	Without potash	626	426	9.6
34	,, ,, ...	645	380	9.7
63	,, ,, ...	620	439	13.6
12	Complete manure..	765	567	6.2
36	,, ,, ...	788	567	11.0
65	,, ,, ...	788	593	10.5
	II. Series. Unrecovered Phosphoric Acid applied in 1889 as Sodium phosphate.			
27	3.65 grms. unrecovered P_2O_5	389	284	5.4
37	,, ,, ,, ...	369	274	5.0
42	,, ,, ,, ...	390	280	3.5

No. o plot.		Straw. grms.	Full grain. grms	Empty grain. grms.
28	6.99 grms. unrecovered P_2O_5	442	326	5.8
38	,, ,, ,, ...	380	282	4.9
43	,, ,, ,, ...	394	293	3.9
29	10.38 grms. unrecovered P_2O_5	452	366	6.2
39	,, ,, ,, ...	444	323	5.1
44	,, ,, ,, ...	465	378	5.2
30	13.98 grms. unrecovered P_2O_5	523	431	6.2
40	,, ,, ,, ...	563	435	7.2
45	,, ,, ,, ...	467	342	5.3
5	18.09 grms. unrecovered P_2O_5	626	451	7.6
17	,, ,, ,, ...	526	452	7.5
24	,, ,, ,, ...	550	472	7.2
31	21.73 grms. unrecovered P_2O_5	555	441	5.4
41	,, ,, ,, ...	604	495	8.2
46	,, ,, ,, ...	525	442	6.7
	III. Series. Unrecovered Phosphoric Acid from Various Phosphates.			
1	No P_2O_5..	421	283	5.1
20	,, ,, ...	386	278	3.3
39	,, ,, ...	374	261	4.9
4	Double Superph., single dose	406	314	4.2
23	,, ,, ,, ,, ...	339	256	3.2
42	,, ,, ,, ,, ...	456	352	5.1

No. of plot.		Straw. grms.	Full grain. grms.	Empty grain. grms.
5	Double Superphosphate, double dose ..	437	360	4.4
24	,, ,, ,, ,, ..	438	360	4.8
43	,, ,, ,, ,, ..	495	392	4.9
6	Precipitated Phosphate, single dose.. ..	456	333	3.6
25	,, ,, ,, ,, ...	413	290	4.2
44	,, ,, ,, ,, ...	466	345	4.7
7	,, ,, double dose ..	469	404	4.2
26	,, ,, ,, ,, ...	538	404	4.2
45	,, ,, ,, ,, ...	536	447	4.8
27	Peruvian Guano, single dose	508	374	4.3
46	,, ,, ,, ,, ...	531	418	4.7
9	,, ,, double dose	570	430	6.2
28	,, ,, ,, ,, ...	538	428	4.6
47	,, ,, ,, ,, ...	671	522	6.2
10	Thomas Phosphate, single dose	489	382	6.2
29	,, ,, ,, ,, ...	514	412	3.7
48	,, ,, ,, ,, ...	535	429	4.7
11	,, ,, double dose	587	464	7.7
30	,, ,, ,, ,, ...	603	492	4.3
	Steamed Bone Dust, single dose	523	422	4.9
	,, ,, ,, ,, ,, ...	546	439	6.6
	,, ,, ,, ,, ,, ...	522	386	5.7
	,, ,, ,, double dose	635	508	4.9
	,, ,, ,, ,, ,, ...	618	526	6.2

No. of plot.		Straw. grms.	Full graiu. grms.	Empty grain. grms.
14	Crude Bone Dust, single dose	516	408	5·5
33	,, ,, ,, ,, ,, ...	446	326	5·7
52	,, ,, ,, ,, ,, ...	520	394	5·2
15	,, ,, ,, double dose	542	432	4·6
34	,, ,, ,, ,, ,, ...	562	441	5·7
53	,, ,, ,, ,, ,, ...	618	489	5·4
35	Bone Ash, single dose..	366	255	3·5
54	,, ,, ,, ,, ...	470	362	5·0
17	,, ,, double dose	470	338	3·2
36	,, ,, ,, ,, ...	466	248	4·5
55	,, ,, ,, ,, ...	480	363	4·3
18	Phosphorite, single dose	377	267	3·8
37	,, ,, ,, ...	435	320	4·1
56	,, ,, ,, ...	456	354	4·6
19	,, double dose	438	304	7·2
38	,, ,, ,, ...	519	404	5·9
57	,, ,, ,, ...	583	453	4·9

農科大學
學術報告
第十二號

IMPERIAL UNIVERSITY.

College of Agriculture.

(Formerly College of Agriculture and Dendrology.)

KOMABA, TOKYO, JAPAN.

BULLETIN No. 12.

Comparative Experiments on the Effect of Various
Phosphatic Fertilizers on Upland Soil,
and
Analysis of Rice Grain.

COMMUNICATED

BY

Dr. O. KELLNER,

Professor of Agricultural Chemistry.

明治二十六年三月

Tokyo, Komaba, March, 2553 (1893).

PRINTED AT THE TOKYO TSUKIJI TYPE FOUNDRY.

COMPARATIVE EXPERIMENTS ON THE EFFECT OF VARIOUS PHOSPHATIC MANURES ON UPLAND SOIL.

BY

Dr. O. Kellner, Y. Kozai, Y. Mori, and M. Nagaoka.

For the sake of comparison with a series of experiments on the effect of various phosphates, commenced in the spring of 1890 in the irrigated paddy field of the college farm[1], we arranged in the following autumn similar experiments on the upland soil.

So far as the chemical composition and physical properties of the two soils are concerned the difference between them is not great. Both consist of volcanic ash mixed with sand, they are both rich in easily decomposable silicates of aluminium, ferruginous compounds and humus, they are both endowed with a high absorptive power for ammonia and phosphoric acid and retain the moisture well; in general they are both characterized as light, ferruginous kinds of loam rich in humus. While the paddy fields are, however, irrigated every summer for about 3 months, and remain, owing to their low situation, rather wet during the other part of the year, the surface of the upland speedily dries up even after long-continued heavy rains, but retains moisture enough to protect the crops from being injured by draught.

According to analysis made in 1882 in conjunction with Mr. *H. Imai* the two soils contained in the air-day state[2]:

	Dry land.	Paddy field.
Hygroscopic water	15.49 %	14.30 %
Loss on ignition	20.01 „	22.30 „
Humus	7.90 „	0.96 „
Nitrogen	0.80 „	0.49 „
Combined water	11.31 „	11.85 „

---

1. See our bulletins No. 9 and 11.
2. Landwirthschaftliche Versuschsstationen, vol. 30. p. 1.

By treatment with hot concentrated hydrochloric (sp. gr. 1.15) and sulphuric acids, and with aqueous hydrofluoric acid, the following results, per cent of the soil dried at 100° C., were obtained.

	Upland Soil.			Paddy Soil.		
	With hydrochloric acid.	With sulphuric acid.	With hydrofluoric acid.	With hydrochloric acid.	With sulphuric acid.	With hydrofluoric acid.
Silica[3]	15.60	1.32	16.96	18.60	1.41	17.42
Alumina	17.67	0.68	4.34	17.05	0.70	3.01
Sesquioxide of iron	6.79	0.37	2.11	3.95	0.40	1.40
Protoxide of iron	4.03	—	—	4.71	—	—
Lime	0.76	0.13	1.42	0.90	0.13	0.94
Magnesia	1.70	0.10	1.34	0.66	0.12	0.70
Potash	0.27	0.10	0.53	0.32	0.09	0.33
Soda	0.23	0.08	0.72	0.19	0.12	0.33
Phosphoric acid	0.34	—	—	0.49	—	—
Sulphuric acid	0.20	—	—	0.16	—	—
Chlorine	0.07	—	—	0.03	—	—
Total fluxed mineral matter..	47.66	2.78	27.42	47.06	2.97	24.13
Undissolved mineral matter.	30.20	27.42	—	27.10	24.13	—

Though the samples taken for the above analyses were not from exactly the same parts of the farm where our experiments are now being carried out, they fairly represent the main features of the chemical condition of the whole farm, and make it evident that the two kinds of soil are of the same geological origin, and are therefore well suited to the purpose in view.

The following 7 kinds of phosphates which, with the exception of the raw crushed bones, are identical with those applied in the researches on the paddy field, were submitted to the experiment:

1. *Double Superphosphate* containing 47.84 % total phosphoric acid, 43.65 % soluble in water and 3.08 % soluble in neutral ammonium citrate.

3. Including the silica rendered soluble in sodium carbonate by the treatment with hydrochloric and sulphuric acids.

2. *Precipitated Calcium Phosphate* containing 29.35 % total phosphoric acid and 24.80 % soluble in neutral ammonium citrate.

3. *Thomas Phosphate* containing 21.75 % total phosphoric acid; 75 % of the fertilizer passed through the standard sieve.

4. *Steamed Bone Dust* containing 21.75 % phosphoric acid, 3.87 % nitrogen, and 1.33 % fat. The separation with chloroform showed that in 100 parts of the manure 0.94 % of the nitrogen was not in the form of bony substance; hence the proportion of nitrogen to phosphoric acid in the bony part was 1 : 7.9, showing that a considerable part of the gelatogenous substance had been extracted.

5. *Crude Bone Dust* containing 19.70 % phosphoric acid, 4.74 % nitrogen and 1.93 % fat. From 100 parts of the manure 0.71 % of the nitrogen could be separated by chloroform as not belonging to the bony part; hence the proportion of nitrogen to phosphoric acid in the bony part was 1 : 4.9 which allows us to conclude that no gelatogenous substance had been extracted from the bones. The low content of fat indicates that the bones had been extracted with benzene or a similar reagent.

6. *Raw Crushed Bones* prepared by ourselves from tubular horse bones from which the meat and tendons had been carefully removed. The coarsely granular mass contained 21.66 % phosphoric acid, 4.61 % nitrogen, and 14.07 % fat. With the help of chloroform it was found that in the bony substance of 100 parts of the whole manure there were 3.93 % nitrogen, the other 0.68 % of nitrogen existed in the form of meat and tendons.

7. *Bone Ash* containing 30.465 % total phosphoric acid; 4.89 % phosphoric acid were dissolved by neutral citrate solution.

The granulation of the manures No. 4–7 as determined with a set of sieves with round holes, was as follows:

Diameter of the particles, millimetres.	Steamed bone dust.	Crude bone dust.	Raw crushed bones.	Bone ash.
	%	%	%	%
Less than 0.25	84.9	37.1	16.6	93.0
0.25--0.5	11.1	25.2	28.1	6.9
0.5 —1	4.0	35.0	54.3	0.1
1 —2	—	1.1	1.0	—

The experiments were made in zinc cylinders open at both ends, 60 centimetres wide and 1 metre long. These were sunk in 6 lines, each of 8 cylinders, into the soil of a level field up to 3 centimetres from the upper edge and very uniformly filled to a hight of 70 centimetres with the yellow subsoil of our farm; the soil was weighed in buckets and after discharging each bucket into the respective cylinder the soil was pressed in with a wooden instrument to avoid the formation of cavities and to obtain the same structure of the particles as exists under natural conditions. On the top of the subsoil there came 30 kilograms of our black topsoil freed with sieves from all rootlets and foreign materials, and previously mixed with precipitated calcium carbonate (1000 kilograms. per hectare) and potassium sulphate (200 kilograms. of potash per hectare). After letting this stand for some days, we added to each cylinder 1.413 grms. of nitrogen in the form of ammonium sulphate (50 kilograms. of nitrogen per hectare), and finally the phosphatic manure was applied several days before sowing. Each phosphate was applied in two quantities, a single and a double, and each quantity was given to 3 cylinders; each phosphate was accordingly tested on 6 different plots. Six cylinders symmetrically situated among the others, did not receive any phosphatic manure. The quantities applied, were as follows:

	Per cylinder grams.		Phosphoric acid per hectare, kilograms.	
	single dose.	double dose.	single dose.	double dose.
Double superphosphate	2.954	5.908	50	100
Precipitated calcium phosphate.	7.22	14.44	75	150
Thomas phosphate	9.74	19.48	75	150
Steamed bone dust	7.35	14.70	60	120
Crude bone dust	8.607	17.214	60	120
Raw crushed bones	7.828	15.656	60	120
Bone ash	9.276	18.552	100	200

Sowing took place on the 29th of October, 1890, the seeds, a variety of barley known as "*golden melone*," about 2 hektolitres per hectare, being distributed on the manured soil with the help of a perforated disk in distances of about 5 centimetres from each other. Over this we applied a covering of 5 kilograms of sifted

topsoil. A fortnight after sowing, new seeds were sown in the few places where the first ones had failed to germinate. During the winter all the cylinders were covered with straw mats, because our soil inclines much to the formation of long ice crystals on the surface, which would lift the young plants and break the roots.

One the 20th of February, 1891, 50 kilograms more of nitrogen as ammonium sulphate were applied per hectare as a top manure.

During the growth, nothing particular was noticed, except that plot No. 24 was seriously injured by lice, and had therefore to be excluded from the analysis. On the 27th of May when the seeds were still somewhat doughy, the plants were cut, dried in the air, and then weighed and analyzed.

The *produce of dry matter* per plot and the action of the fertilizers on the yield will be seen from the following table.

No. of Plots.	Phosphoric, acid, applied. grms.	Kind of Phosphate.	Dry matter produced grms.	Plus-yield over the plots without phosphoric acid. grms.	Plus-yield caused by 100 grms. of phosphoric acid. grms.
3, 11, 19.	0	No phosphatic manure.	72.8	—	—
30, 38, 46.	0				
1, 9, 17.	2.120	Thomas phosphate ...	215.9	143.1	6750
2, 10, 18.	4.240	" " ...	322.1	249.3	5880
4, 12, 20.	1.413	Double superphosphate	269.6	196.8	13928
5, 13, 21.	2.826	" "	385.7	312.9	11072
6, 14, 22.	2.120	Precipitated calcium phosphate	250.7	177.9	8387
29, 37, 45.	4.240		347.0	274.2	6467
7, 15, 23.	2.826	Bone ash	150.1	77.3	2735
8, 16, 24.	5.652	" "	256.7	183.9	3254
25, 33, 41.	1.696	Steamed bone dust ...	262.0	189.2	11156
26, 34, 42.	3.392	" " " ...	353.2	280.4	8267
27, 35, 43.	1.696	Crude bone dust... ...	201.6	128.8	7594
28, 36, 44.	3.392	" " "	318.4	245.6	7241
31, 39, 47.	1.696	Raw crushed bones ...	199.5	126.7	7471
32, 40, 48.	3.392	" " " ...	314.4	241.6	7124

According to these results the yield had been considerably increased by all the kinds of phosphatic fertilizers applied, but the double doses of these manures, though causing a far larger produce than the single ones, did not display their full action. Hence we must exclude the figures obtained with the larger doses of phosphates from further consideration, while those with the smaller ones will furnish a sufficiently reliable basis for a judgment on their relative action on the increase of the crop. Assuming the increase of crop caused by 100 grms. of the smaller dose of phosphoric acid in the form of superphosphate to be 100, we obtain the following figures for the relative effect on the production of dry matter.

Double superphosphate	...100.0
Steamed bone dust	... 80.1
Precipitated calcium phosphate	... 60.2
Crude bone dust	... 54.5
Raw crushed bones	... 53.7
Thomas phosphate...	... 48.5
Bone ash...	... 19.6

Before entering into a discussion of these results we may consider the *proportions of phosphorie acid consumed by* the barley plants from the soil and manure, as found by the analysis of the crop.

Phosphoric acid per plot.	In the manure. grms.	In the crop. grms.	Consumed from the manure.	
			Grms.	Per cent of the phosphoric acid applied.
No phosphatic manure ...	0	0.129	—	—
Double superphosphate ...	1.413	0.433	0.304	21.5
" " ...	2.826	0.573	0.444	—
Steamed bone dust	1.696	0.410	0.281	16 6
" " "	3.392	0.547	0.418	—
Precipitated calcium phos.	2.120	0.421	0.292	13.8
" " "	4.240	0 529	0.400	—
Crude bone dust...	1.696	0.333	0.209	12.4
" " "	3 392	0.501	0.372	—
Raw crushed bones	1.696	0.343	0.214	12.6
" " "	3.392	0.469	0.340	—
Thomas phosphate	2.120	0.407	0.278	13.1
" "	4.240	0.536	0.407	—
Bone ash	2.826	0.270	0.141	5 0
" "	5 652	0.393	0.264	—

In harmony with the action of the phosphatic fertilizers on the produce of dry matter, we find from the above table that from the larger doses of phosphates invariably more phosphoric acid was consumed than from the smaller ones, wherefore the results obtained with the latter will yield reliable information also on the relative assimilability of the various forms of phosphoric acid. Assuming also here the quantity consumed from the superphosphate (21.5) to be 100 and calculating on this basis the relative assimilability of other forms of phosphoric acid, we obtain the following results, to which we add for comparison the relative effect on the increase of dry matter.

	Relative assimilability.	Relative effect on the increase of dry matter.	Relative manurial value, concerning the first crop.*
Double superphosphate	100	100	**100**
Steamed bone dust	77.2	80.1	**79**
Precipitated calcium phosphate ...	64.2	60.2	**62**
Crude bone dust	57.7	54.5	**56**
Raw crushed bones...	58.6	53.7	**56**
Thomas phosphate	60.9	48.5	**55**
Bone ash	23.3	19.6	**21**

The two series of figures on the assimilability and effect on the produce coincide tolerably well, with the one exception of these obtained by the Thomas phosphate. In the case of this, as well as the other somewhat slowly acting manures, the phosphoric acid rendered available by the gradual decomposition in the soil, entered the plants too late to influence to its full capacity the production of dry matter, wherefore the plants supplied with these phosphates became richer in phosphoric acid than those manured with the more easily assimilable superphosphate. The analysis show, indeed, that the crop produced with Thomas phosphate was the richest in phosphoric acid, it contained in the dry matter 0.188 %; next comes the content of 0.180 % in the crop with bone ash, 0.177 % in that without any phosphate, 0.172 % in the crop with raw crushed bones, 0.168 % in that with precipitated phosphate, 0.166 % with superphosphate, 0.165 % with

* Average calculated from the two preceding columns.

crude bone dust, and 0.157 %, the lowest content, in the crop produced with steamed bone dust. Although the difference between these figures is not great, it affects considerably the results calculated for the relative assimilability. By the way, we may point out in this place that the proportion of phosphoric acid in the barley crop, in the average of the above figures 0.172 % of the dry matter, almost coincides with that (0.168 %) in paddy rice (straw and grain).

With reference to the manurial value of the various forms of phosphoric acid our experiments have shown that on dry land the first rank must be awarded to the *superphosphate*, of the phosphoric acid of which 21.5 % was recovered in the crop. Owing to its richness in sesquioxides of iron and aluminium our soil is not particularly favorable to the action of this manure, as the soluble phosphate if applied in the autumn is sure to be converted during the winter, to a comparatively large extent, into basic compounds which are less available to the roots.—Next in value comes the *steamed bone dust* which yielded 16,6 % of its phosphoric acid to the crop, and which approaches, in its effect (79), very near to that of the superphosphate (100). This result is about eight times that (10) obtained by P. Wagner in his comparative experiments, and shows that, under favorable climatic conditions, the steamed bone dust is one of the best kinds of concentrated commercial fertilizers. The effect displayed by it in our experiments must not be even regarded as a maximum attainable only under exceptionally favorable conditions, because our specimen of bone dust was not of the best kind but of rather inferior quality owing to the partial extraction of gelatinoid (see p. 3).—The *precipitated calcium phosphate* which ranks next to the steamed bone dust and of the phosphoric acid of which only 13.8 % was consumed by the crop, is likewise an excellent phosphatic manure, and according to other observers, frequently has a still better action than in our experiments.—The *crude bone dust* and *raw crushed bones* which differed from each other in the size of the particles and in their content of fat—the former containing only 1.93, the latter 14.07 %, were nevertheless consumed to the same extent (12.4 resp. 12.6 %)

and must both be considered to have the same very considerable manurial value (56). For their application on dry land, the conversion into steamed bone dust may be profitable in many cases also in Japan, as by this operation a very fine powder is obtained, which admits of a better distribution on the soil, and undergoes decomposition with great ease; but we are inclined to recommend to the farmers rather a preparatory fermentation of the raw crushed bones in the compost bed whenever it is sought to accelerate the action of this manure.—The *Thomas phosphate* has almost exactly the same manurial value as the crude bone dust and raw bones; it decomposes a little more slowly in the soil than the two latter phosphates, and should therefore be always applied as early as possible.—The lowest effect was observed with the *bone ash*, which, owing to high temperature during the incineration of the raw bones, contains the phosphates in a very insoluble and partly fused state and should accordingly be converted into superphosphate before application.

It affords moreover some interest to compare the results obtained with the above phosphates on *upland soil* with those previously found in our experiments with rice on *irrigated paddy land*. The principal figures of the two reries of experiments are the following:

	Dry land. Barley.		Paddy field. Rice.	
	Consumed from 100 parts of phosphoric acid.	Relative manurial value.	Consumed from 100 parts of phosphoric acid.	Relative manurial value.
Superphosphate...	21.5	100	24.1	100
Steamed bone dust	16.6	79	14.2	56
Precipitated calcium phosphate.	13.8	62	25.1	106
Crude bone duste	12.4	56	14.6	60
Thomas phosphate	13.1	55	13.7	53
Bone ash	5.0	27	6.6	28

These figures show a pretty close coincidence as to the relative manurial values of the double superphosphate, crude bone dust, Thomas phosphate, and bone ash. From the phosphoric acid of these manures the barley consumed on the dry land a little less than the rice on the irrigated soil, probably because the former

crop has shorter roots and ripens (in May) before the high temperature of the summer months carries the decomposition of the phosphates in the soil so far as during the growth of rice (July to October); yet these conditions did not specially affect any of the above fertilizers, but acted on all alike and thus did not impair the proportionality of the two series of figures given for the relative manurial effect. With the steamed bone dust and precipitated calcium phosphate the case is different. The former manure acted better on the dry land, probably because in the porous soil to which the oxygen of the air has easy access, the gelatogenous bone tissue previously steamed under a high pressure is more readily decomposed than the original bone tissue without previous gelatinization; comparative experiments on the effect of the nitrogen of crude and steamed bone manure made by us on the same dry field, proved indeed, that the nitrogen of the steamed bone dust also acts much better than that of the crude one, while in the irrigated paddy soil the two had the same effect. The superior action of the precipitated calcium phosphate on the paddy rice is certainly due to the better distribution which can be given to it in the soft muddy paddy soil.

In order to determine further the *after-action* of the various phosphates we mixed the soil of each plot carefully with the roots and stubble of the barley and sowed on the 1st of June, 1891, *millet* (Panicum crus corvi) after applying on the previous day 50 kilograms. of nitrogen as ammonium sulphate to all plots alike. The germination was quite regular, but the subsequent growth, though not disturbed by the weather or any other external cause, was not so vigorous as we had expected. On the 25th of August, when the millet was nearly ripe, it was cut, dried, weighed, and analyzed by Mr. *T. Yamada*, a post-graduate of the college. The results were was follows (per plot):

Phosphoric acid originally applied. grms.	Kind of Phosphate.	Dry matter produced. grms.	Plus-yield over the plots without phosphoric acid.		Plus-yield by 100 grms. of phosphoric acid. 1st and 2nd crops. grms.
			Grms.	Caused by 100 grms. of phosphoric acid. grms.	
0	No phosphatic manure ...	47 9	—	—	—
1.413	Double superphosphate ...	144.1	96.2	6801	20729
2.826	" " ...	164.1	116.2	4112	15184
1.696	Steamed bone dust	143.5	95.6	5637	16793
3.392	" " "	179 2	131 3	3871	12138
2.120	Precipitated calcium phos.	162.7	114.8	5415	13802
4.240	" " "	171.7	123.8	2920	9387
1.696	Crude bone dust	154.8	106.7	6291	13885
3 392	" " "	258.1	210.2	6197	13438
1.696	Raw crushed bones	128.1	80.2	4729	12200
3.392	" " "	164.2	116.3	3429	10553
2 120	Thomas phosphate	88 7	40.8	1925	8675
4.240	" "	138.7	90 8	2193	8073
2.826	Bone ash	107.3	59.4	2102	4837
5.652	" "	150.8	102.9	1821	5075

There was, accordingly, in all cases a considerable action of the unrecovered phosphoric acid, which, in some cases (crude bone dust and precipitated calcium phosphate) was as high, or nearly as high, as after the fresh application of the manure to the first crop. The best after-effect was displayed by the double superphosphate; then followed the crude bone dust, steamed bone dust, precipitated phosphate, raw crushed bones, Thomas phosphate, and finally the bone ash. A calculation also based on the plus-yield produced by 100 grams of phosphoric acid applied in the smaller doses, gives the following figures for the action of the various phosphates on the *first two crops* (winter barley and millet):

	Relative effect on the production of dry matter.
Double superphosphate	100
Steamed bone dust	81.0
Precipitated calcium phosphate	66.6
Crude bone dust	67.0
Raw crushed bones	58.5
Thomas phosphate	41.9
Bone ash	23.3

The quantities of phosphoric acid consumed from the original manure by the second crop, are shown in the following table:

Phosphoric acid per plot.	In the original manure. grms.	In the crop. grms.	Consumed from the manure by the 2nd crop.		Consumed by the two first crops, per cent of the phosphoric acid applied.
			grms.	per cent of the phosphoric acid applied.	
No phosphatic manure ...	—	0.093	—	—	—
Double superphosphate ...	1.413	0.247	0.154	10.8	32.3
" " ...	2.826	0.278	0.185	—	—
Steamed bone dust	1.696	0.217	0.124	7.3	23.9
" " "	3.392	0.320	0.227	—	—
Precipitated calcium phos.	2.120	0.269	0.176	8.3	22.1
" " "	4.240	0.327	0.234	—	—
Crude bone dust	1.696	0.275	0.182	10.7	23.1
" " "	3.392	0.484	0.391	—	—
Raw crushed bones	1.696	0.259	0.166	9.8	22.4
" " "	3.392	0.335	0.242	—	—
Thomas phosphate	2.120	0.159	0.066	3.1	16.2
" "	4.240	0.215	0.122	—	—
Bone ash	2.826	0.188	0.095	3.4	8.0
" "	5.652	0.258	0.165	—	—

If we would estimate the manurial value of the manures only from the quantity of nutrients consumed from them by plants, the above figures relating to the two first crops would indicate that the phosphoric acid in the form of steamed and crude bone dust, raw

crushed bones, and precipitated calcium phosphate have a value of about ⅔, that of Thomas phosphate ½, and of bone ash ¼ of that of superphosphate. Such a method, however, would not lead to quite a right idea as already mentioned, because the consumption may take place too late to enable the plant to make full use of the manure during its growth for the production of dry matter. Hence, it is more correct to take into account also the increase of the crop, and to deduce from the two series of results the relative value of the fertilizer. We get thus the following figures for the manurial values:

	Relative effect on the production of dry matter.	Relative assimilability.	Relative manurial value. 1st & 2nd crop.
Double superphosphate	100	100	**100**
Steamed bone dust	81.0	74.0	**77.5**
Precipitated calcium phosphate...	66.6	68.4	**67.5**
Crude bone dust	67.0	71.5	**69**
Raw crushed bones	58 5	69.4	**64**
Thomas phosphate	41.9	50.2	**46**
Bone ash	23.3	24.8	**24**

After the millet had been harvested, the soil of the cylinders was digged up, well mixed with the stubble and roots, and left in a loose condition until the 19th of the October, when per plot 1.413 grams of nitrogen (50 kilograms. per hectare) were applied in the form of ammonium sulphate. Two days later *wheat* was sown with the help of the same perforated zinc plates which had already been used for the barley and millet. Where the seeds failed to germinate, new ones were sown a fortnight afterwards. During the winter the cylinders were again covered with mats every day from about sunset till the morning, but in spite of all care, some of the plots with the single dose of phosphoric acid in the form of Thomas phosphate and steamed bone dust were injured by frost.— On January 29th, 1892, 0.7065 grams of nitrogen as ammonium sulphate per plot (25 kilograms per hectare) was applied as a top manure, and this was repeated on the 23rd of March. The wheat was cut when nearly ripe on the 28th of June, and had the following weight (dry matter) per plot:

Kind of Phosphate.	Phosphoric acid originally applied. grms.	Dry matter produced. grms.	Increase of the yield over the plots without phosphoric acid.		Increase by 100 grms. phosphoric acid. 1st, 2nd, and 3rd crop. grms.
			Grms.	Caused by 100 grms. phosphoric acid. grms.	
No phosphatic manure ...	0	39.6	—	—	—
Double superphosphate ...	1.413	95.0	55.4	3921	24650
" " ...	2.826	166.1	126.5	4476	19660
Steamed bone dust*... ...	1.696	(71.7)	—	—	(20805)
" " "	3.392	775.7	136.1	4012	16150
Precipitated calcium phos.	2.120	123.3	83.7	3950	17752
" " "	4.240	193.1	153.5	3620	13007
Crude bone dust	1.696	221.5	181.9	10725	24610
" " "	3.392	314.9	275.3	8116	21554
Raw crushed bones	1.696	255.3	215.7	12718	24918
" " "	3.392	338.9	299.3	8824	19377
Thomas phosphate	2.120	77.9	38.3	1807	10482
" "	4.240	111.0	71.4	1684	9757
Bone ash	2.826	144.1	104.5	3698	8535
" "	5.652	201.5	161.9	2864	7939

Calculating now the *relative increase* of dry matter produced by equal quantities of the various forms of phosphoric acid, assuming the effect of the superphosphate to be 100, we find the following results:

	Relative increase of dry matter. 1st, 2nd, & 3rd crops.
Double superphosphate	100
Steamed bone dust	84.4
Precipitated calcium phosphate	72.0
Crude bone dust...	99.9
Raw crushed bones	101.1
Thomas phosphate	42.5
Bone ash	34.6

* As the plots with the smaller dose of steamed bone dust had been injured by frost, we calculated in the above table the increase caused by 100 grams phosphoric acid of this dose from the yield obtained with the larger quantity of that fertilizer.

The proportion of phosphoric acid consumed per plot by the wheat, as found by the analysis of the crop, are recorded in the following table :

Phosphoric acid originally applied. grms.	Kind of phosphate.	In the crop. grms.	Consumed from the manure by the 3rd crop.		Consumed by the first three crops, per cent of the phosphoric acid applied.
			grms.	per cent of the phosphoric acid applied.	
0	No phosphoric manure ...	0.102	—	—	—
1.413	Double superphosphate...	0.204	0.102	7.2	39.5
2.826	" " ...	0.311	0.209	7.4	—
1.696	Steamed bone dust * ...	(0.172)	—	(7.6)	(31.5)
3.392	" " " ...	0.357	0.255	7.6	—
2.120	Precipitated calcium phos.	0.286	0.184	8.7	30.8
4.240	" " "	0.437	0.335	7.9	—
1.696	Crude bone dust	0.482	0.380	22.4	45.5
3.392	" " "	0.774	0.672	19.8	—
1.696	Raw crushed bones... ...	0.551	0.449	26.5	48 9
3 392	" " "	0.794	0.692	20.4	—
2.120	Thomas phosphate... ...	0.210	0.108	5.1	21.3
4.240	" "	0.275	0.173	4.1	—
2.826	Bone ash	0.332	0.230	8 2	16.2
5.652	" "	0.453	0.351	6 2	—

The relative assimilability and manurial value of the various phosphates is, according to the preceding results obtained with 3 consecutive crops, as follows :

	Relative assimilability.	Relative increase, dry matter of the 3 crops.	Relative manurial value.
Double superphosphate	100	100	**100**
Steamed bone dust	79.8	84.4	**82**
Precipitated calcium phosphate ...	78.0	72.0	**75**
Crude bone dust	115.2	99.9	**108**
Raw crushed bones	124.0	101.1	**113**
Thomas phosphate	54.0	42.5	**48**
Bone ash	41.0	34.6	**38**

* See the note on p. 14.

After the wheat had been harvested we cultivated as the 4th crop *buckwheat* with a supply of 75 kilograms per hectare of nitrogen in the form of ammonium sulphate. Sowing took place on the 19th of July. The development of this plant, like that of the millet in the preceding season, was rather inferior, as all assimilable phosphoric acid had been consumed by the wheat, the buckwheat thus depending on the small quantities which gradually became available through decomposition in the soil. On the 29th of September when the seeds were still green, we cut the plants.

The yield of dry matter is shown by the following table:

Phosphoric acid in the original manure. grms.		Yield. Dry matter. grms.	Increase over the plots not supplied with phosphoric acid. Grms.	Increase over the plots not supplied with phosphoric acid. By 100 grms. phosphoric acid. grms.	Increase caused by 100 grms. phosphoric acid. 1st, 2nd, 3rd, and 4th crops. grms.
0	No phosphatic manure ...	9.1	—	—	—
1.413	Double superphosphate...	11.8	2.7	191	24841
2.826	" " ...	13.5	4.4	156	19816
1.696	Steamed bone dust... ...	9.3	0.2	—	(20805)
3.392	" " "	14.3	5.2	153	16303
2.120	Precipitated calcium phos.	11.5	2.4	113	17865
4.240	" " "	22.6	13.5	319	13326
1.696	Crude bone dust	22.7	13.6	802	25412
3.392	" " "	41.4	32.3	952	22506
1.696	Raw crushed bones ...	38.5	29.4	1734	26652
3.392	" " " ...	53.9	44.8	1321	20698
2.120	Thomas phosphate... ...	11.1	2.0	95	10577
4.240	" "	11.7	2.6	61	9818
2.826	Bone ash	11.8	2.7	96	8631
5.652	" "	13.5	4.4	79	8018

According to these results the relative increase caused by equal quantities of the various forms of phosphoric acid, is as follows:

	Relative increase, 4 crops.
Double superphosphate	100
Steamed bone dust	83.8
Precipitated calcium phosphate	71.9
Crude bone dust...	102.4
Raw crushed bones	107.3
Thomas phosphate	42.6
Bone ash	34.7

The analysis of the backwheat showed that the following quantities of phosphoric acid had been consumed from the soil and manure:

Phosphoric acid in the original manure. grms.		Phosphoric acid in the whole crop. grms.	Phosphoric acid consumed from the manure		Phosphoric acid consumed by the 1st, 2nd, 3rd, and 4th crops. %
			grms.	Per cent of the phosphoric acid applied.	
0	No phosphatic manure ...	0.025	—	—	—
1.413	Double superphosphate...	0.036	0.011	0.8	40.3
2.826	" " ...	0.037	0.012	0.4	—
1.696	Steamed bone dust... ...	0.027	0.002	0.1	31.6
3.392	" " "	0.043	0.018	0.5	—
2.120	Precipitated calcium phos.	0.034	0.009	0.4	31.3
4.240	" " "	0.072	0.047	1.1	—
1.696	Crude bone dust	0.074	0.049	2.9	48.8
3.392	" " "	0.130	0.105	3.1	—
1.696	Raw crushed bones... ...	0.132	0.107	6.3	55.2
3.392	" " "	0.193	0.168	5.0	—
2.120	Thomas phosphate... ...	0.029	0.004	0.2	21.5
4.240	" "	0.031	0.006	0.1	—
2.826	Bone ash	0.054	0.029	1.0	17.2
5.652	" "	0.108	0.073	1.3	—

The relative assimilability and manurial value of the phosphoric acid of the fertilizers experimented on as found with the 4 consecutive crops, is as follows:

	Relative assimilability.	Relative increase of crops.	Relative manurial value.
Double superphosphate	100	100	**100**
Steamed bone dust	78.4	83.8	**81**
Precipitated calcium phosphate.	77.7	71 9	**75**
Crude bone dust...	120.1	102.4	**113**
Raw crushed bones	137.0	107.3	**122**
Thomas phosphate	53.5	42.6	**48**
Bone ash	42.7	34.7	**39**

The phosphoric fertilizers applied in 1890 displayed according to the preceding results further distinct effect after they had been for nearly 2 years in soil from which crops were continually taken. Doubtless, this condition will last for a considerable time yet, and it will, therefore, be most interesting to continue the experiments on the same plan for several seasons to come.

Upon comparing the figures given for the relative increase of crop and the relative assimilability, we notice that the differences between them became in some cases gradually wider, the longer the phosphates had been in the soil. This need not surprise us, since it is plain that the later crops find only the most insoluble remainders of the phosphatic fertilizers, which become available but slowly, and are always consumed somewhat too late to participate to their full capacity in the production of arganic matter. It is evident that this must be particularly noticeable with the large doses of phosphates, for which the following figures result from a calculation based on the assumption that the relative action on the increase of crop and the quantities of phosphoric acid consumed from the large dose of the superphosphate is 100.

	Relative increase. 4 crops.	Relative consumption of phosphoric acid. 4 crops.	Relative manurial value.
Double superphosphate	100	100	100
Steamed bone dust	82.3	90.0	86
Precipitated calcium phosphate... ...	67.3	80.0	74
Crude bone dust	113.7	150.8	132
Raw crushed bones	104.5	141.2	123
Thomas phosphate	49.4	55.5	52
Bone ash	40.5	49.9	45

In spite of these differences, the results obtained with the large doses coincide in their main features with these found with the small ones, and they would show a still closer resemblance with the latter, had we based the calculation not on the results with the superphosphate but on those obtained with another fertilizer (steamed bone dust). The superphosphate shows a somewhat peculiar department in our soil; the larger its doses, the more is left unconsumed by the first crop and the more of its phosphoric acid combines with copious sesquioxides of the soil, in which form it is less easily dissolved and consumed by the roots.

Concerning the manurial value of the various phosphates, particular importance must be attached to the proportion of phosphoric acid consumed. We therefore append to this paper a diagram, where the co-ordinates show the rate of the phosphoric acid consumed from 100 grams in the manure, and the abscissa is marked with the time of the development of each crop in months.* In this place we may take into consideration the figures which show how much phosphoric acid, per cent of the quantity applied, was taken up by each crop.

A. Percentage of Phosphoric Acid Consumed by Each Single Crop.

Length of action of the phosphates, months.	7	3	10	3
Kind of crops.	1st crop. Barley.	2nd crop. Millet.	3rd crop. Wheat.	4th crop. Buck-Wheat.
Double superphosphate	21.5	10.8	7.2	0.8
Steamed bone dust	16.6	7.3	7.6	0.1
Precipitated calcium phosphate ...	13.8	8.3	8.7	0.7
Crude bone dust	12.4	10.7	22.4	2.9
Raw crushed bones	12.6	9.8	26.5	6.3
Thomas phosphate	13.1	3.1	5.1	0.2
Bone ash	5.0	3.4	8.2	1.0

* The table B on the next page contains all data required the construction of this diagram.

B. Percentage of Phosphoric Acid Consumed by the Consecutive Crops.

Length of action of the phosphates, months.	7	10	20	23
Number of crops.	First crop.	First 2 crops.	First 3 crops.	First 4 crops.
Double superphosphate	21.5	32.3	39.5	40.3
Steamed bone dust	16.6	23.9	31.5	31.6
Precipitated calcium phosphate ...	13.8	22.1	30.8	31.3
Crude bone dust...	12.4	23.1	45.5	48.4
Raw crushed bones	12.6	22.4	38.9	55.2
Thomas phosphate	13.1	16.2	21.3	21.5
Bone ash	5.0	8.0	16.2	17.2

C. Percentage of Phosphoric Acid Consumed per Months.*

Length of action of the phosphates, months.	7	3	10	3
Kind of crops.	1st crop. Barley.	2nd crop. Millet.	3rd crop. Wheat.	4th crop. Buck-Wheat.
Double superphosphate	3.1	3.6	0.7	0.3
Steamed bone dust	2.4	2.4	0.8	0 03
Precipitated calcium phosphate ...	2.0	2.8	0.9	0.1
Crude bone dust...	1.8	3.6	2.2	1.0
Raw crushed bones	1.8	3.2	2.7	2.1
Thomas phosphate	1.9	1.0	0.5	0.1
Hone ash	0.7	1.1	0.8	0.3

* The figures in this table do not convey an entirely correct idea of the rapidity of action of the various phosphates, because the various crops did not grow with the same intensity. While the two winter crops (barley and wheat) are retarded in their growth during nearly 4 months, the summer crops (millet and buckwheat) attain their full development within 3 months.

From these results and our preceding explanations we may deduce the following conclusions:

1. Of all phosphates applied, the double *superphosphate* was the most effective in the beginning, its rate of consumption by the first two crops cultivated in the first 10 months not being surpassed by any of the other fertilizers. After that time, however, its solubility diminished, probably because the dibasic compounds formed after its application are gradually converted into tribasic and polybasic ones, from which the phosphoric acid cannot be readily dissolved by the roots. It is, therefore, the best suited to crops of rapid development and to soils of medium absorptive power for phosphoric acid, and should be chiefly applied to crops cultivated in the spring or summer, a few days before sowing or transplanting.

2. The *precipitated calcium phosphate* which in our case consisted chiefly of dicalcium phosphate mixed with some tricalcium phosphate was less active than the superphosphate, because its distribution in the upland soil cannot be accomplished to that extent which is easily attained with the superphosphate. The monocalcium phosphate, the principal ingredient of the latter, dissolves in the fluids of the soil, and is then precipitated, thus assuming a state of extremely fine division, while the distribution of the precipitated calcium phosphate depends merely on the mechanical process of mixing. Though less rapid in the beginning, the action of the latter phosphate will usually continue longer than that of superphosphate.

3. The three kinds of bone manure, *steamed bone dust, crude bone dust* and *raw crushed bones* gave very remarkable results. The first crop consumed from the steamed bone dust considerably more than from the two raw fertilizers, but the after-effect of the unrecovered phosphoric acid of the former was much inferior to that of the two latter manures. It must, however, be kept in mind that our specimen of steamed bone dust had been deprived of a part of its gelatinoid substance, which, during its decay in the soil, assists in the dissolution of the phosphatic ingredients of bones, and accelerates the action on crops. Had our steamed

bone dust been in a normal condition, its effect would have certainly not much inferior to that of the superphosphate on the first crops. On the other hand, there is no great difference in the assimilability of the phosphoric acid of the crude bone dust and raw crushed bones. These two manures had a good effect on the first two crops, but after having undergone decomposition in the in the soil for one year, their solubility increased so enormously that the third crop consumed from them more than even the superphosphate yielded to the first crop. This observation is of great practical importance. It goes to show that in countries with a warm climate and with copious rain, as in Japan, bone manures are most valuable even in quite a raw state, and that by early application or by a preparatory fermentation in the compost bed their manurial value may be easily and cheaply raised to that of the superphosphate. During our experiments on the college farm we have had frequent opportunity of proving that bone dust has a specially good effect on cereals sown in autumn, not only in reference to its phosphatic ingredients but also to its content of nitrogen. The presence of fat does not deteriorate its value, but seems rather to secure a better after-effect, as in our experiments the raw crushed bones with 14.07 % fat yielded more phosphoric acid to the 3rd and 4th crops than the crude bone dust with only 1.33 % fat.

4. The *Thomas phosphate* displayed with regard to the first crop as well as to the 3 subsequent ones approximately half the effect of the superphosphate. The excellent after-effect attributed to this fertilizer by P. Wagner has not been, up to the present, perceptible in our experiments, in spite of the richness of our soil in humus, and the copious rainfall.

5. *Bone ash* is, as we had anticipated, a very insoluble manure acting but slowly on the first two crops, but of increased efficacy in course of time. It should always be converted into superphosphate before its application.

ANALYSES OF RICE GRAIN,

CARRIED OUT IN CONJUNCTION WITH *S. MACHIDA*

BY

Dr. O. Kellner and M. Nagaoka.

The specimens of rice for these analyses were kindly furnished to our laboratory by the managers of the second rice exhibition held in the spring of 1891 in Fukagawa, Tokyo. As only large quantities (12 *koku* = 22 hectolitres) were admitted there, we may be sure that our analyses have reference only to grain as it was really harvested, and not to specimens specially picked out for competition. We analyzed altogether 9 samples which ranged according to their quality as follows:

Order of quality.	Variety.	Locality of production. Province.	Weight of 1000 grains. grms.
I. Superior	Sekitori.	Ise.	19.02
II. ,,	Kokurabozu.	Higo.	24.12
III. Medium good.	San-ryu-ichi-sun.	Owari-	27.00
IV. ,, ,,	Sekitori.	Mino.	19.25
V. Medium.	Sekitori.	Ise.	18.69
VI. ,,	Omase.	Higo.	25.26
VII. Inferior.	Ishi shiro.	Etchyu.	22.41
VIII. ,,	Wakazakura.	Ugo.	23.01
IX. ,,	Ikezoko.	Mino.	22.03

were in the brown form

All 9 specimens had been hulled but not whitened (cleaned). They were found to have the following percentage composition.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Water	13.20	13.50	13.50	13.24	12.96	13.70	14.04	13,43	14.27
IN THE DRY MATTER:									
Crude protein ...	10.51	9.41	9.66	11.12	10.40	9.04	9.84	9.91	11.16
,, fibre ...	1.31	1.11	1.32	0.97	0.92	0.90	1.28	1.02	1.10
,, fat. ...	2.97	2.34	2.47	2.77	2.41	2.29	2.56	2.61	2.25
Nitrogen-free extract... ...	83.80	85.81	85.12	83.69	84.71	86.31	84.83	84.94	83.90
Ash	1.41	1.33	1.43	1.45	1.56	1.46	1.49	1.51	1.59
Total nitrogen ...	1.682	1.505	1.545	1.763	1.677	1.447	1.572	1.585	1.785
Albuminoid nitrogen ...	1.596	1.397	1.437	1.596	1.509	1.318	1.406	1.501	1.698
Non-albuminoid nitrogen ...	0.086	0.108	0.108	0.167	0.168	0.129	0.169	0.084	0.087
,, per cent of total N. ...	5.1	7.1	7.0	9.5	10.0	8.9	10.7	5.3	4.9

It is plain from these figures that the commercial value has no relation to the chemical composition of the rice, a fact already frequently noticed in analyses of other cereal grains. The case is different if the same variety is cultivated under similar climatological conditions with different manures; then the rule seems to be applicable that good grain is comparatively rich in nitrogenous substances.

For the sake of comparison we may quote here a few analyses made in the Osaka sanitary laboratory of hulled, brown not whitened, rice from other countries:

	Corea. %	Siam. %	Anam. %
Water	13.93	12.64	12.75
IN THE DRY MATTER:			
Crude protein	9.19	10.01	8.75
,, fibre	1.54	1.23	1.53
,, fat	2.49	2.53	2.48
Nitrogen-free extract	85.03	84.79	85.53
Ash	1.75	1.44	1.71

In the above mentioned exhibition we collected as many specimens of Japanese rice as possible and mixed for analysis equal quantities of it in order to obtain figures which might represent the medium composition of this important vegetable product with greater accuracy than do the few analyses hitherto made. Thus we mixed 578 specimens and subjected the mixture to an analysis, which gave the following results:

Water	13.54 %
IN THE DRY MATTER:	
Crude protein	10.12 „
„ fibre	1.12 „
„ fat	2.52 „
Nitrogen-free extract ...	84.79 „
Ash	1.47 „
Total nitrogen	1.617 „
Albuminoid nitrogen ...	1.495 „
Non-albuminoid „ ...	0.122 „
„ per cent of total N. ...	7.4 „

IN 100 PARTS OF ASH:	
Potash	22.47
Soda	4.55
Lime	2.93
Magnesia	12.60
Ferric oxide	1.63
Phosphoric acid	48.31
Sulphuric acid	0.23
Silica	6.53
Chlorine	0.91

明治廿六年三月廿五日印刷
明治廿六年四月二十日出版

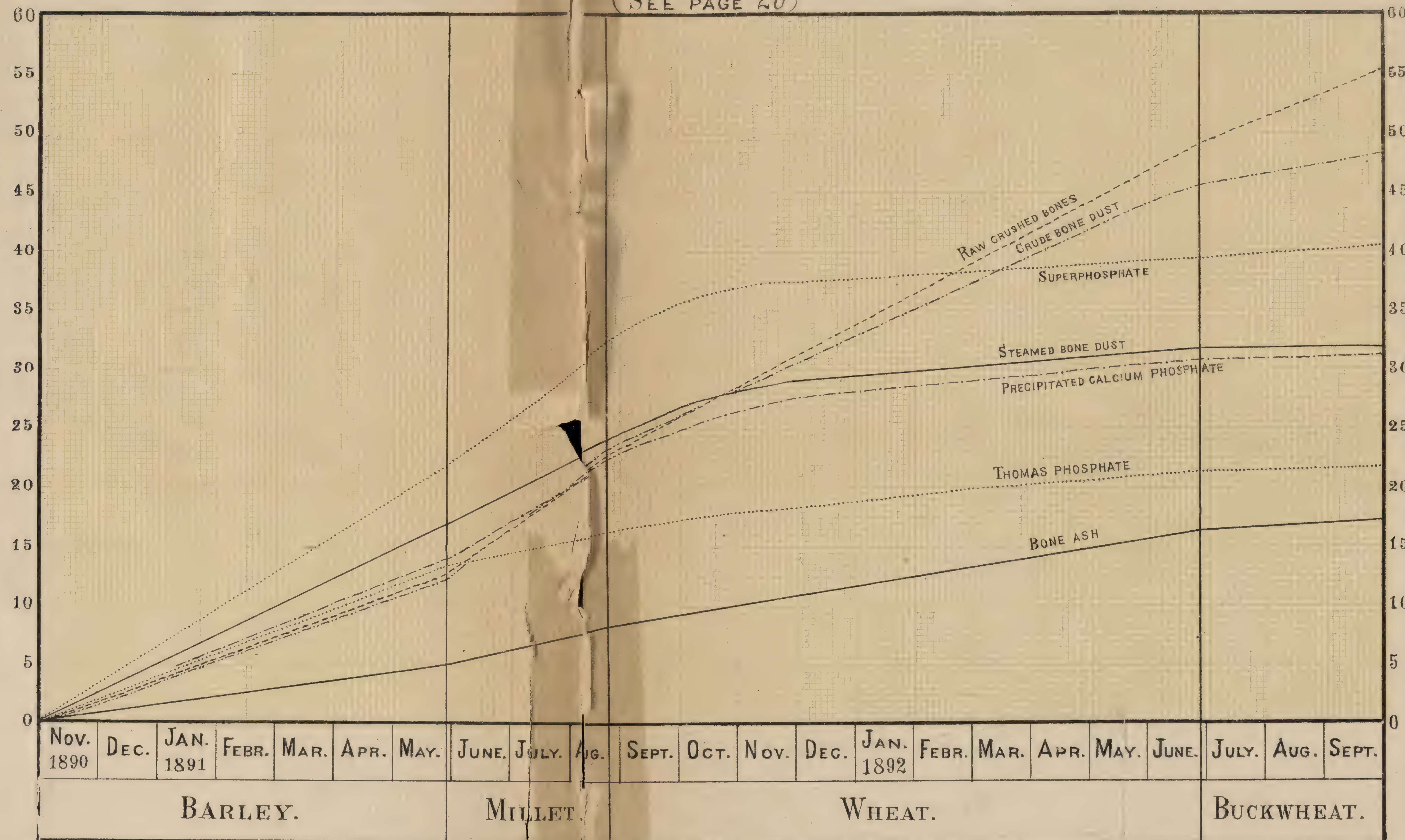
編輯兼發行者　農科大學

印刷者　曲田成
京橋區築地二丁目十七番地

印刷所　東京築地活版製造所
京橋區築地二丁目十七番地

Diagram showing the Rate of Consumption of Phosphoric Acid from Various Phosphates by 4 Consecutive Crops.

(See page 20)



Graham